

PANIC05  
28 Oct. 2005

# The Physics Program at J-PARC

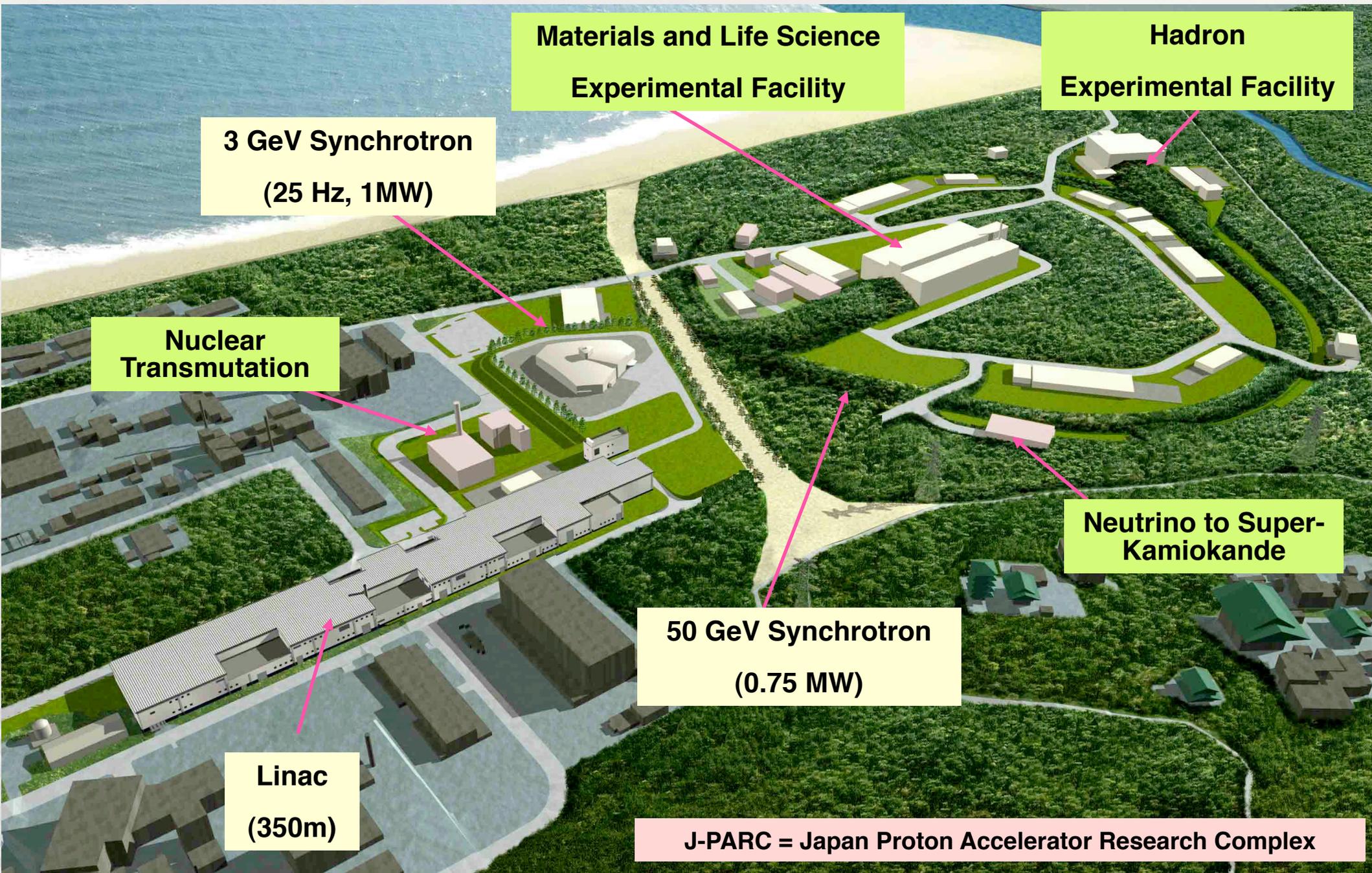
Tomofumi Nagae  
*J-PARC Project Office, KEK*

*Thanks to T. Kobayashi, J. Imazato, S. Sawada, M. Aoki, Y. Masuda*

# Contents

- Status of J-PARC
- Nuclear Physics Program
  - Strangeness Nuclear Physics
  - Hadron Physics
- Particle Physics Program
  - Neutrino Oscillation Experiment (T2K)
  - Kaon and Muon Decay Experiments
  - Fundamental Physics with neutron
- Summary

# J-PARC Facility



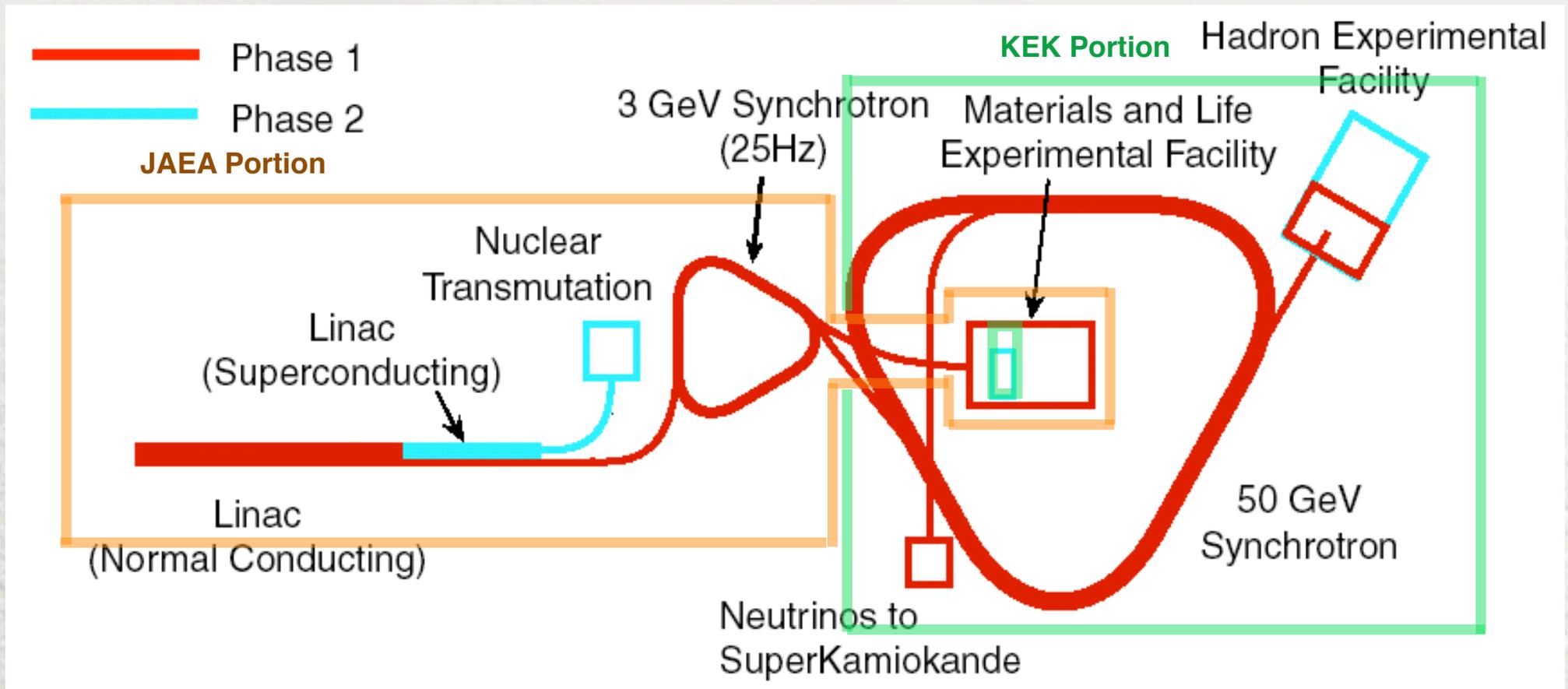
Joint Project between KEK and JAEA

Tokai

J-PARC Site in Sep. 2005



# Phase 1 and Phase 2



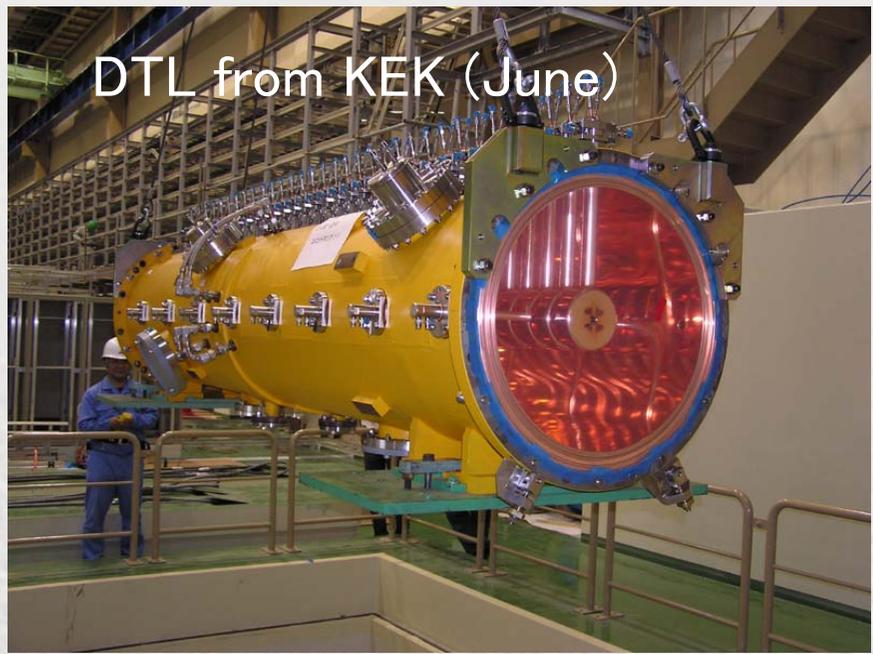
- Phase 1 + Phase 2 = 1,890 Oku Yen (= \$1.89 billions if \$1 = 100 Yen).
- Phase 1 = 1,527 Oku Yen (= \$1.5 billions) for 7 years.
- JAEA: 860 Oku Yen (56%), KEK: 667 Oku Yen (44%).

# Toward J-PARC Center

Agreement between KEK and JAERI, Aug. 2005



# Installation of Acc. Elements



DTL from KEK (June)



3 GeV Ceramics Tube (July)



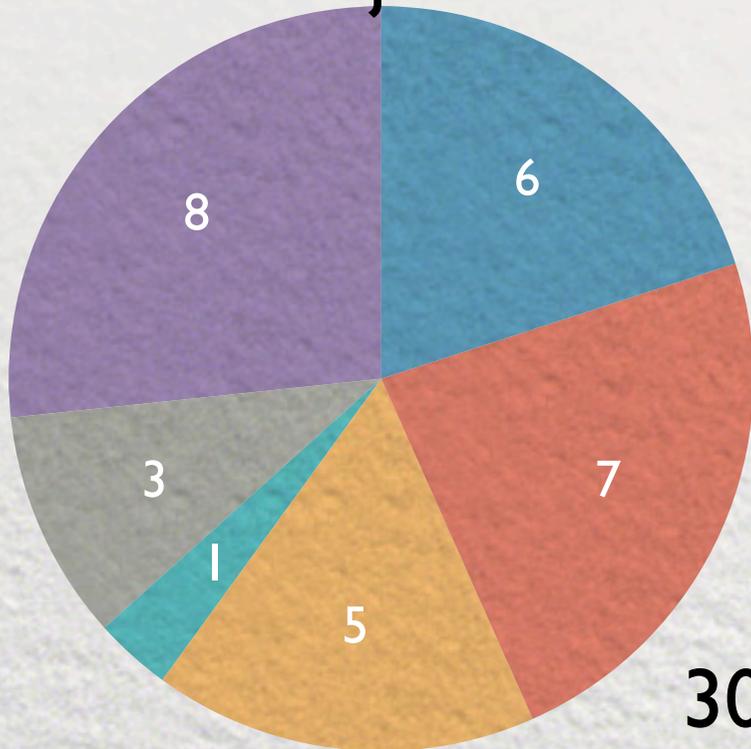
RFQ from KEK (July)



RFQ Installation (July)

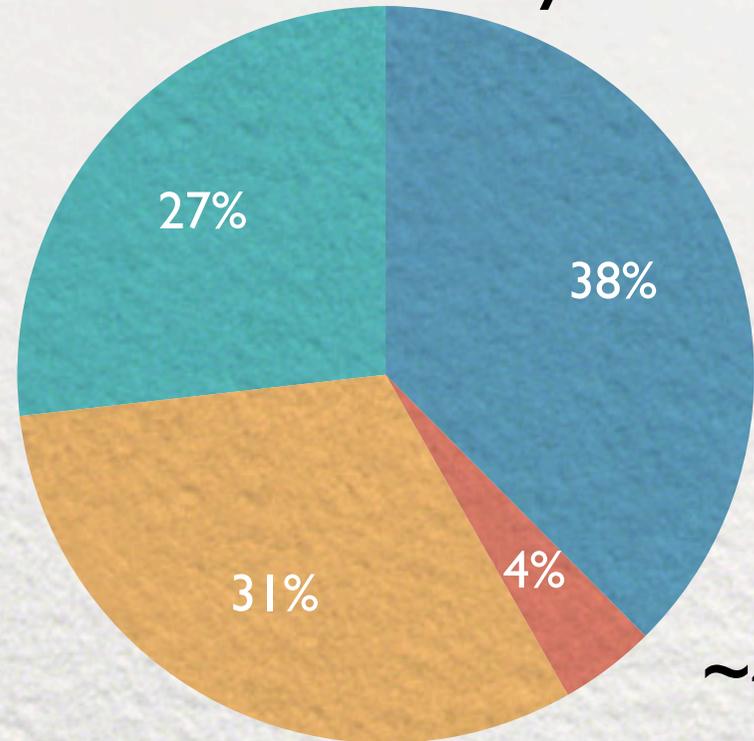
# Letters of Intent for Nuclear and Particle Physics

## Subjects



30 LoI's

## Nationality



~480 authors

- Strangeness Nuclear Physics
- Hadron Physics
- K decay
- Neutrino
- $\mu$  decay
- Facility

- Japan
- Asia
- North America
- Europe

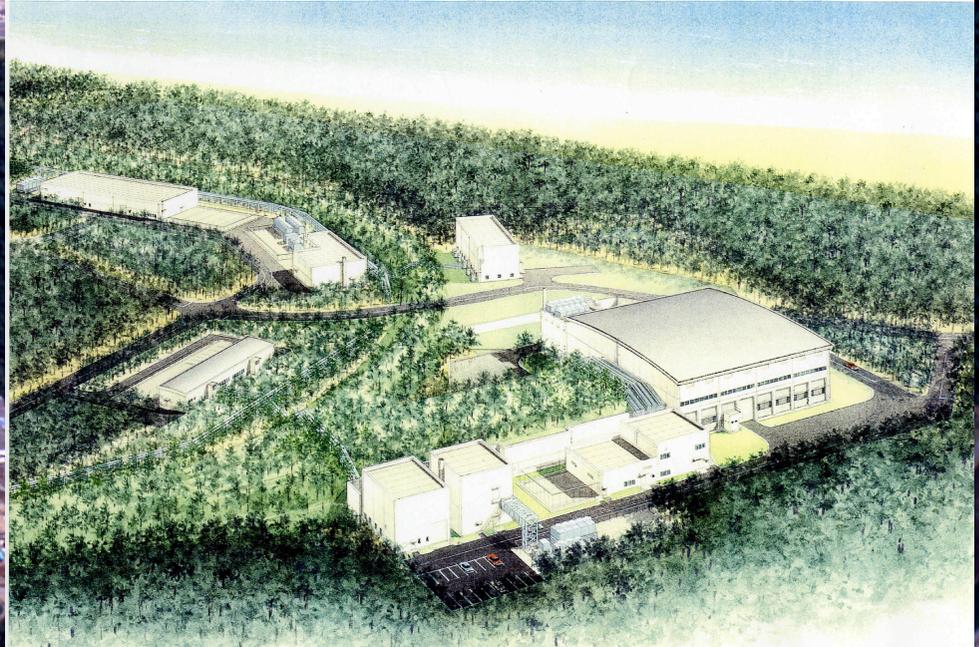
Called in 2002

Two Day-I Exp. selected: L06 & L10

# Hadron Experimental Hall

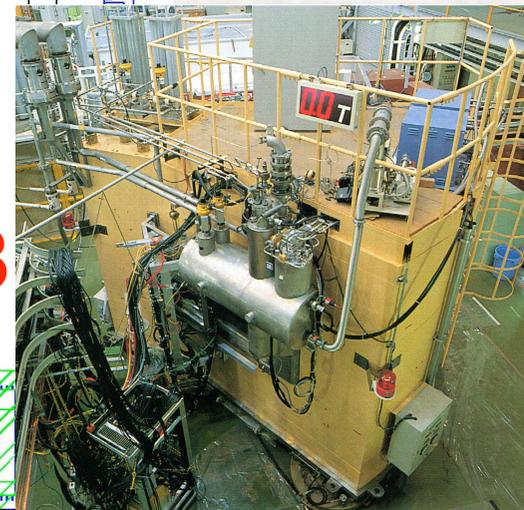
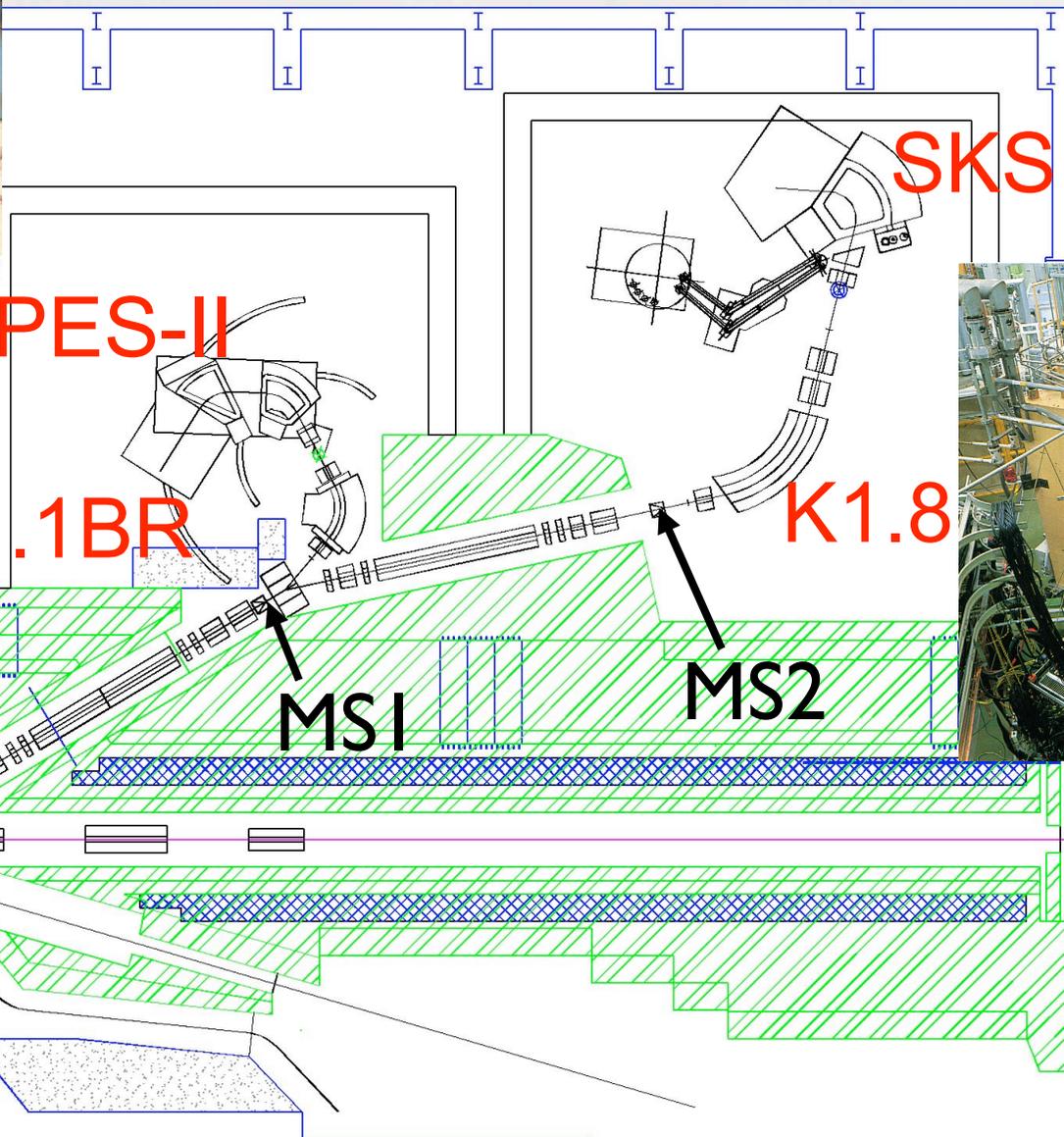


Strangeness Nuclear Physics  
Hadron Physics  
K Decay Experiments



# Layout Option - K1.8+K1.1BR

$\sim 10^7$  K-/sec,  $K/\pi > 1$



# LOIs in

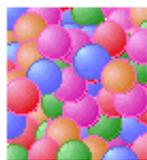
## Strangeness Nuclear Physics at J-PARC

- **L06**: New Generation Spectroscopy of Hadron Many-Body Systems with Strangeness  $S=-2$  and  $-1$  (K. Imai et al.)
- L07: Hyperon-Proton Scattering Experiments at the 50-GeV PS (M. Ieiri et al.)
- L08: High-Resolution Reaction Spectroscopy of  $S=-1$  Hypernuclei (H. Noumi et al.)
- L09: Neutron-rich  $\Lambda$  hypernuclei by the double-charge exchange reaction (T. Fukuda et al.)
- **L10**: Study of Dense  $\bar{K}$  Nuclear Systems (T. Nagae et al.)
- L21: Precise Measurement of the Nonmesonic Weak Decay of  $A=4,5$   $\Lambda$  Hypernuclei (S. Ajimura et al.)

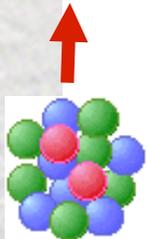
# L06: New generation spectroscopy of hadron many-body systems with strangeness $S=-2$ and $-1$

## New Hadron Many-Body Systems with Strangeness

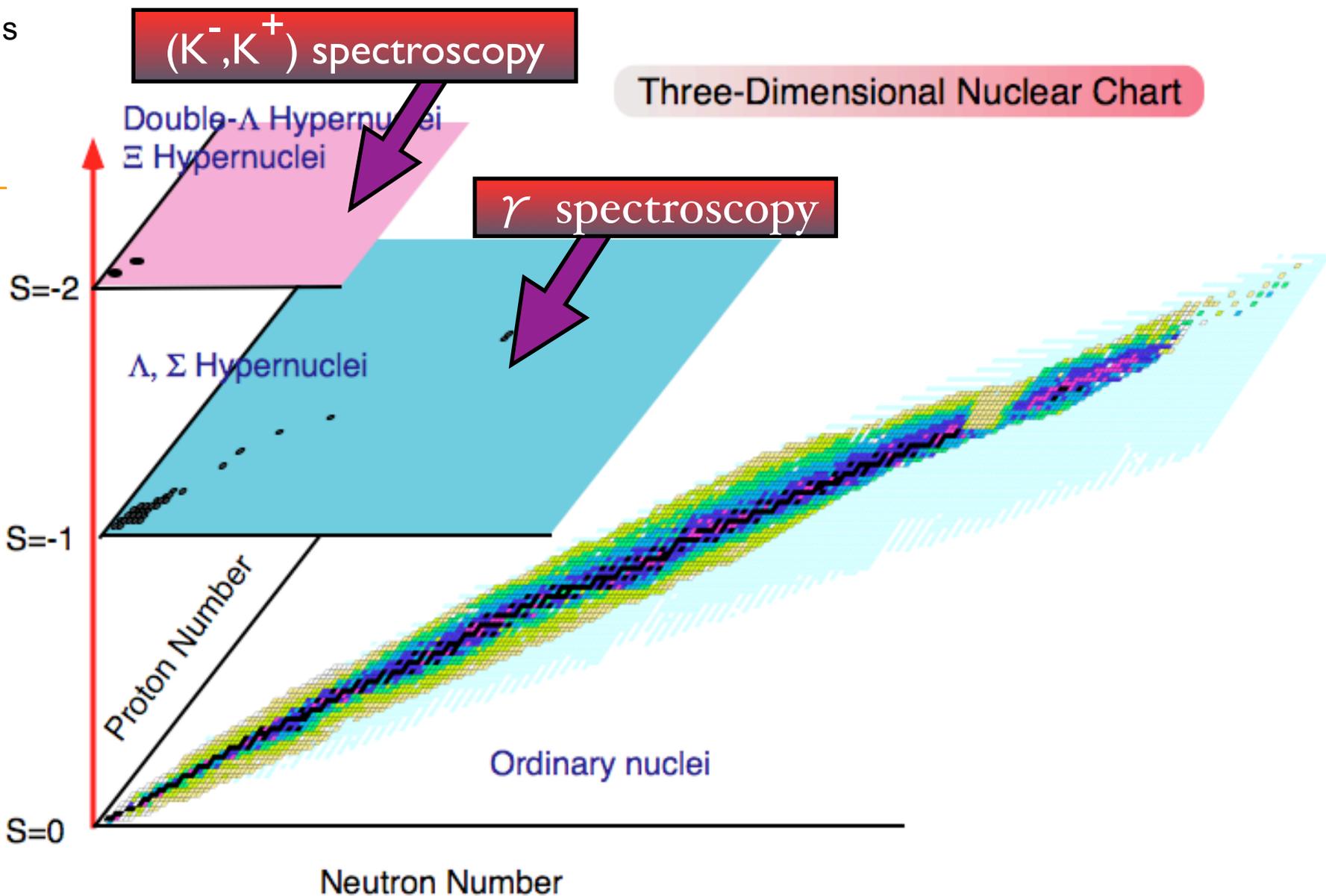
$N_u \sim N_d \sim N_s$



$p, n, \Lambda, \Xi^0, \Xi^-$

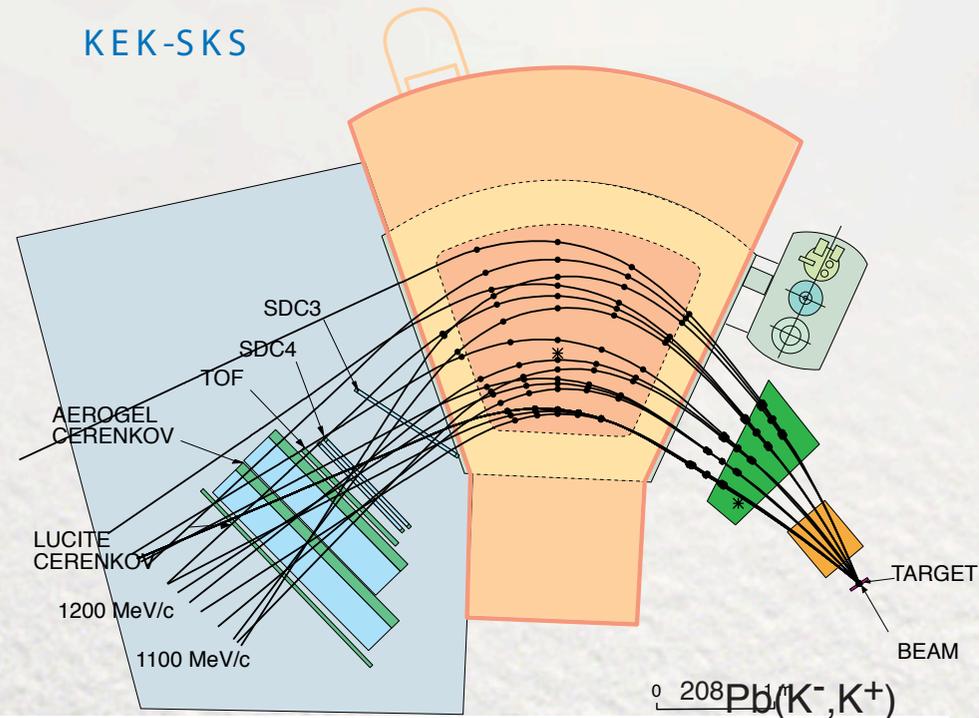


Strangeness



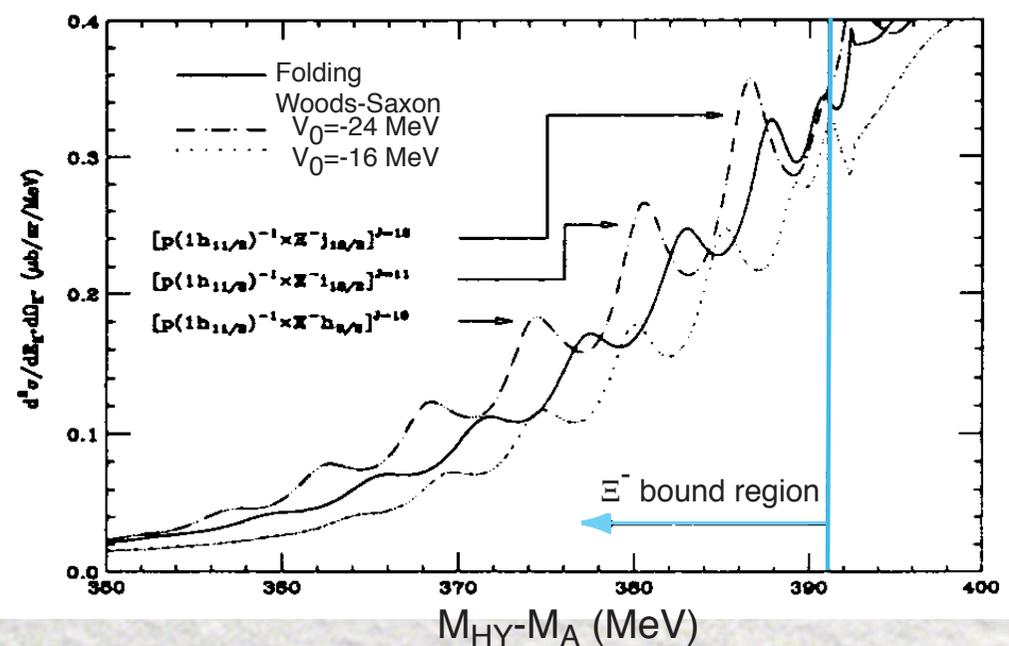
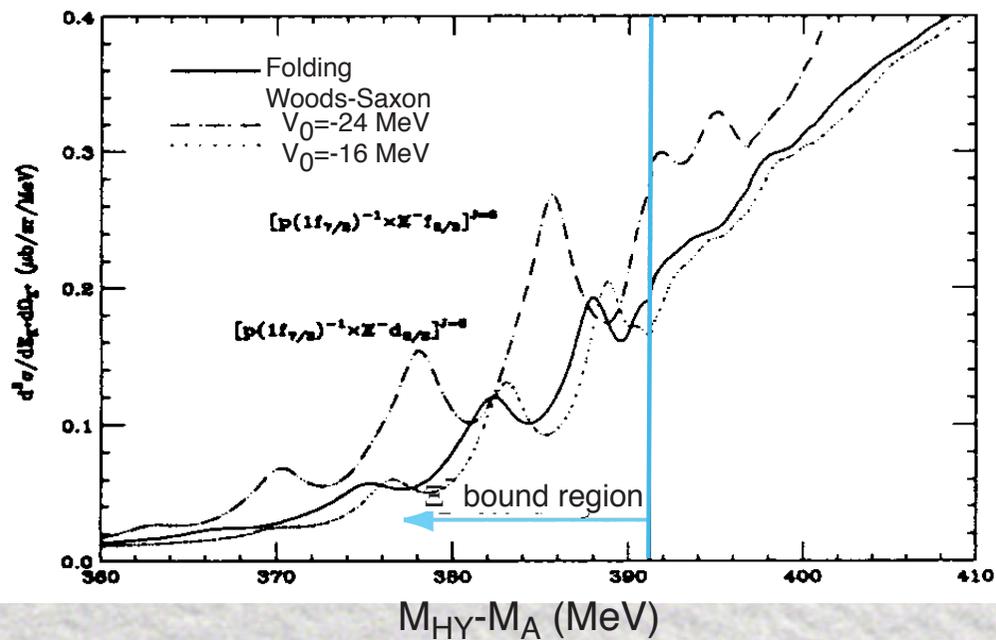
# $\Xi$ Hypernuclei with $(K^-, K^+)$

- **2 MeV** FWHM resolution
- $\sim 6$  events/day/MeV for 50 msr,  $2\text{g/cm}^2$ -thick Pb  $\sim 20$  days



$^{58}\text{Ni}(K^-, K^+)$

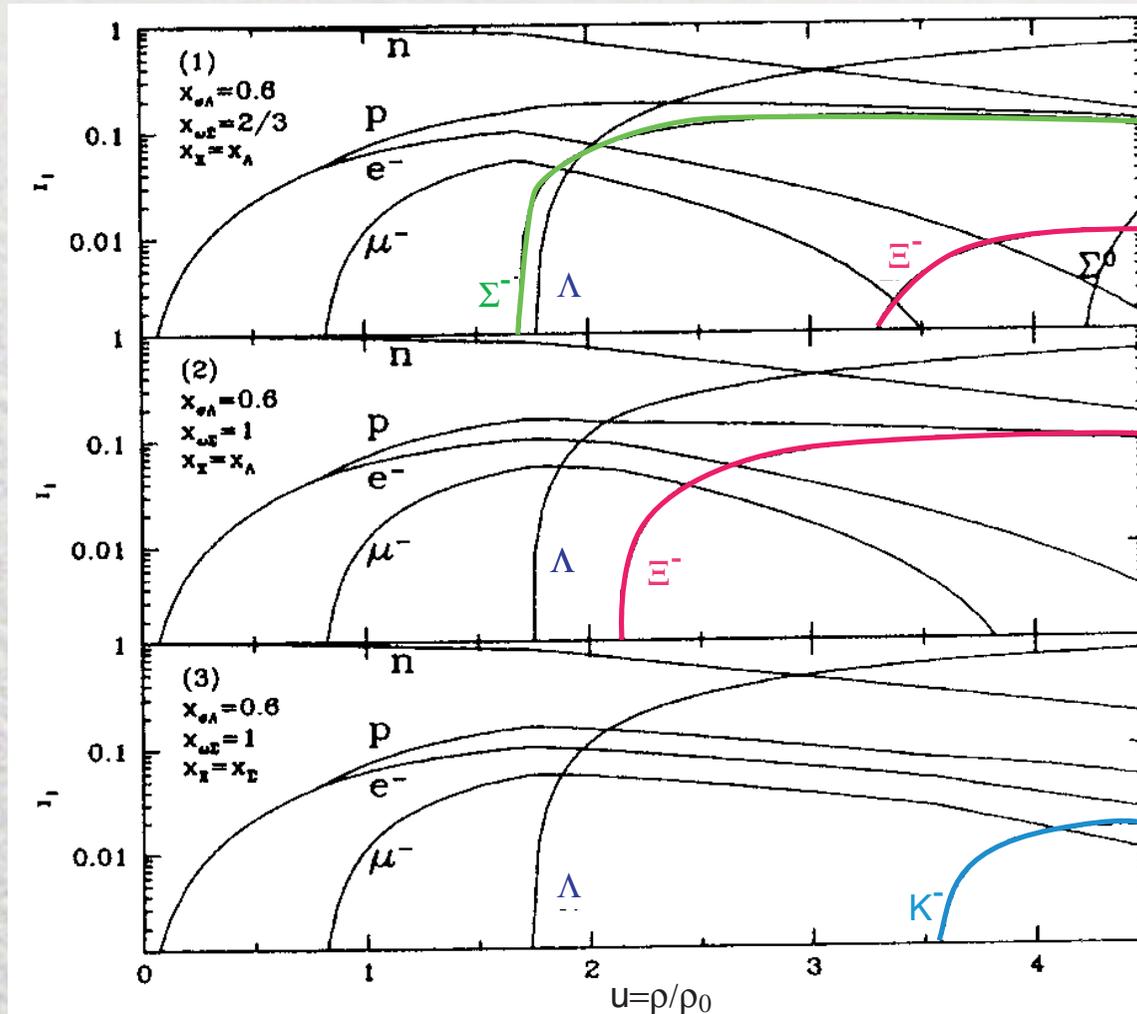
$^{208}\text{Pb}(K^-, K^+)$



# $\Xi$ hypernuclei potential ?

- $\Lambda, \Sigma^-, \Xi^-, K^-$  in Neutron Star Core ?

- Chemical Potential:  $\mu_B = m_B + \frac{k_F^2}{2m_B} + U(k_F)$

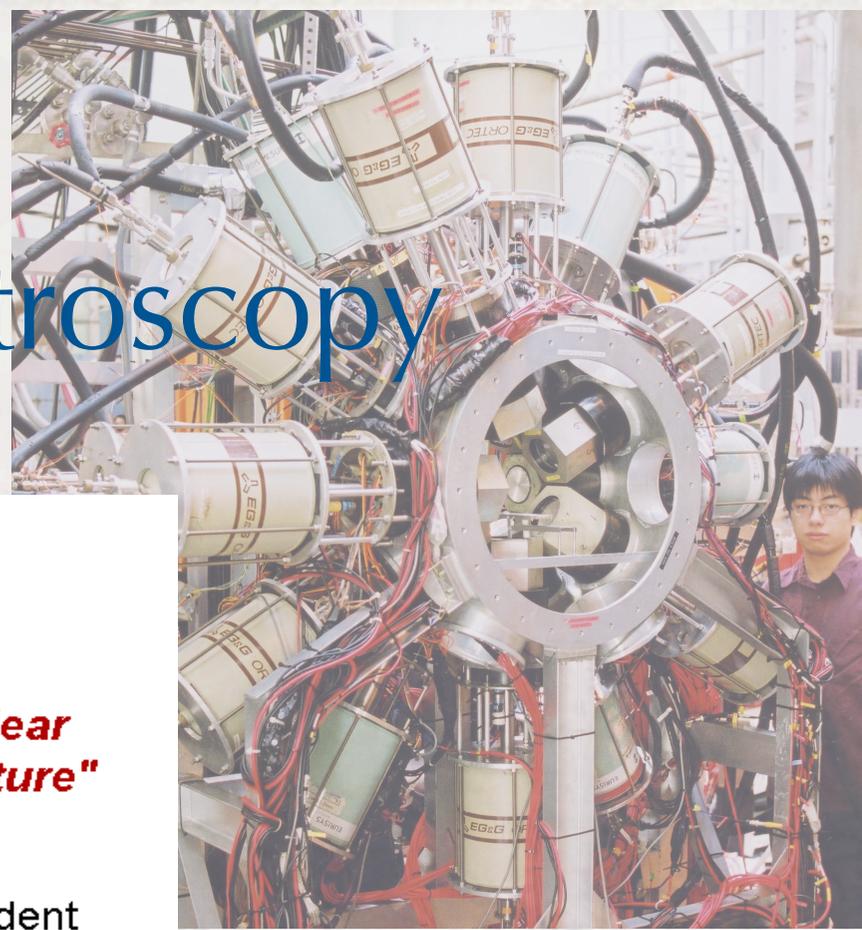


$$U_{\Sigma} < 0, U_{\Xi} < 0$$

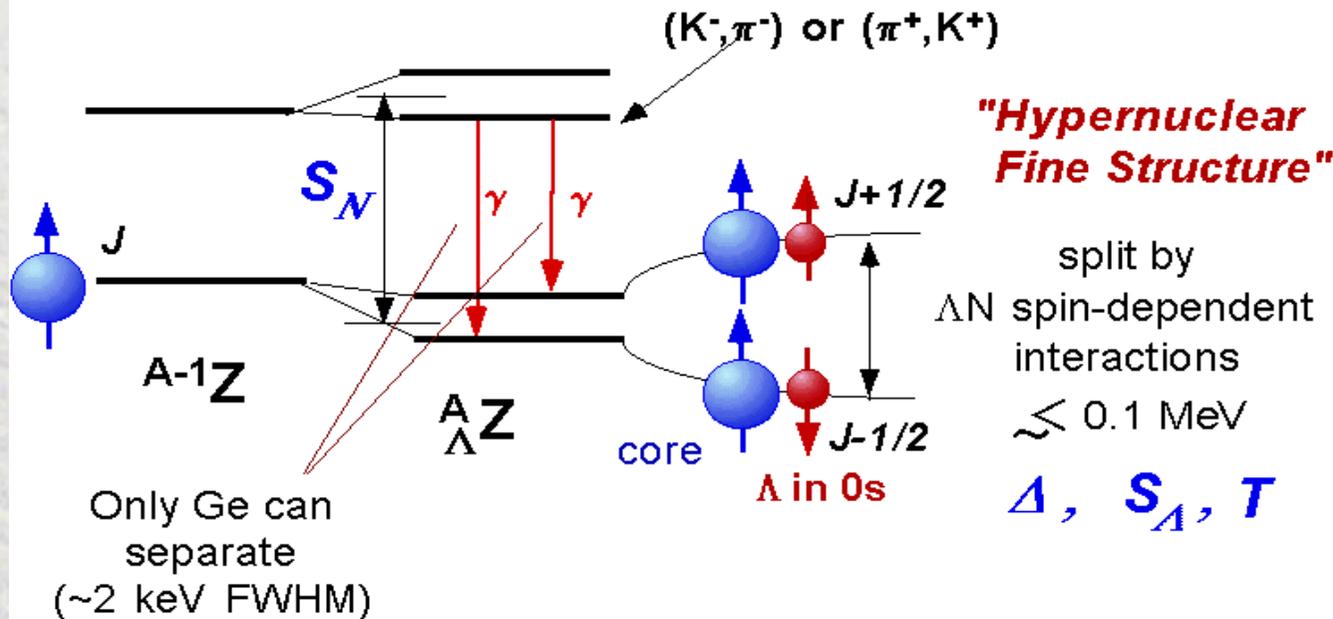
$$U_{\Sigma} > 0, U_{\Xi} < 0$$

$$U_{\Sigma} > 0, U_{\Xi} > 0$$

# Success of Hypernuclear $\gamma$ spectroscopy



- Low-lying levels of  $\Lambda$  hypernucleus



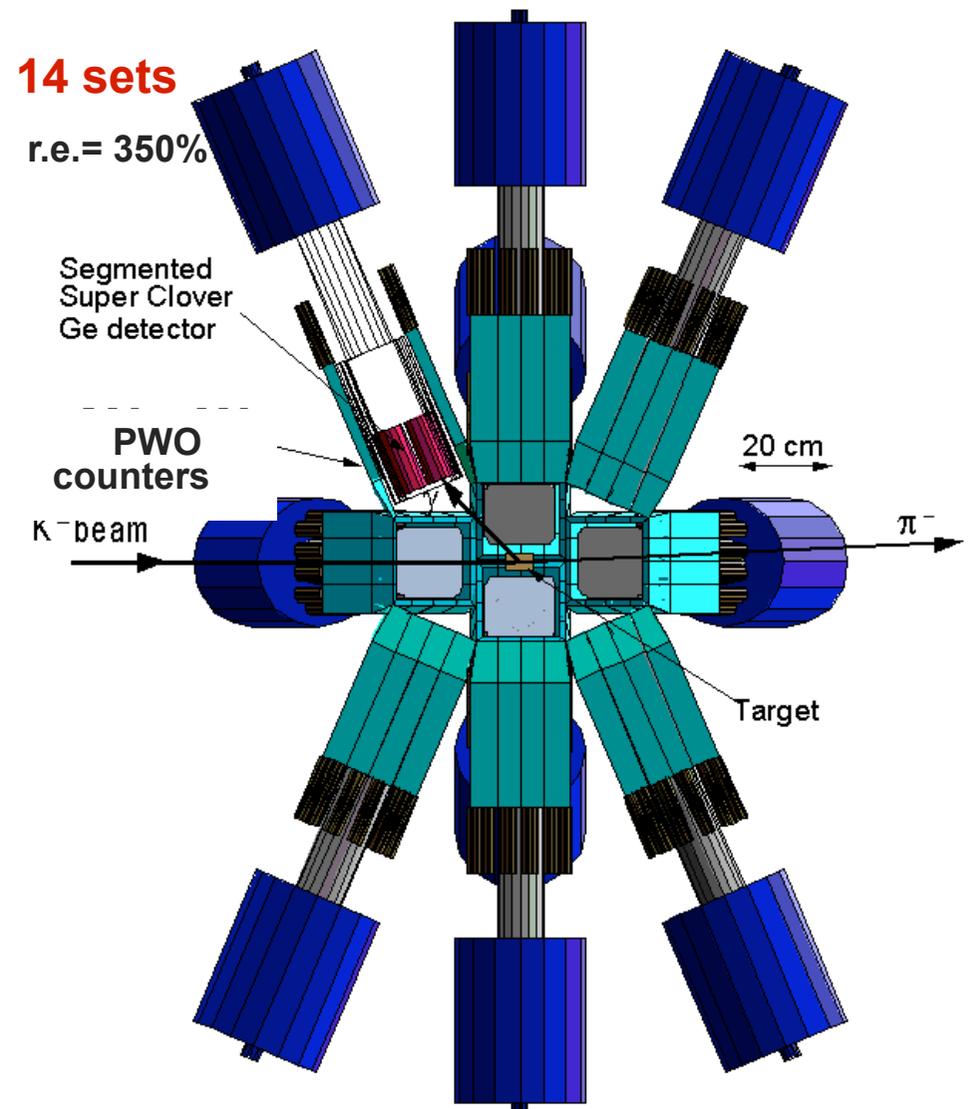
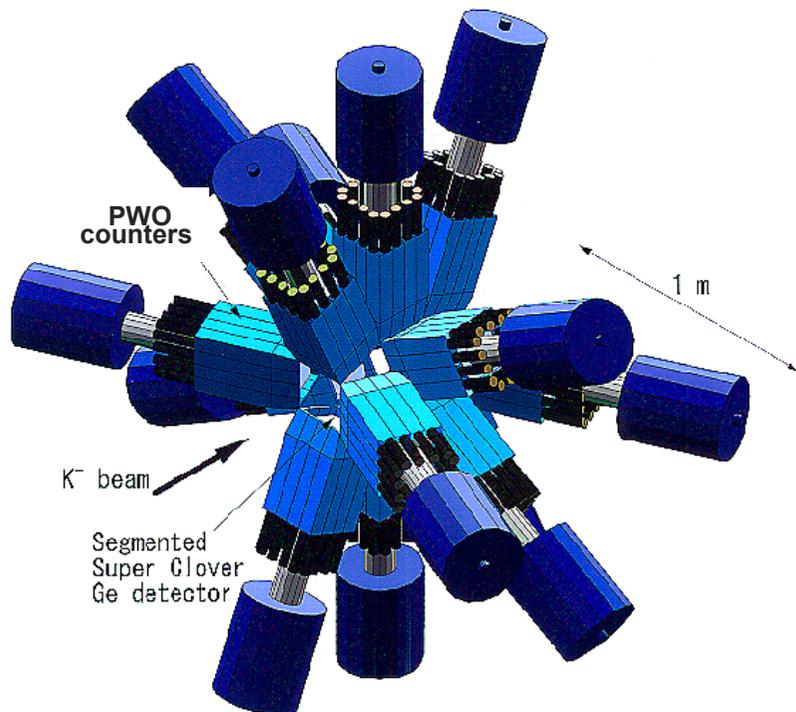
- 2-body  $\Lambda N$  effective interaction

$$V_{\Lambda N}^{\text{eff}} = V_0(r) + \underset{\Delta}{V_{\sigma}(r) \vec{s}_A \vec{s}_N} + \underset{S_A}{V_{\Lambda}(r) \vec{l}_{\Lambda N} \vec{s}_A} + \underset{S_N}{V_N(r) \vec{l}_{\Lambda N} \vec{s}_N} + \underset{T}{V_T(r) S_{12}}$$

*p-shell : 4 radial integrals for  $p_N s_A$  w.f.*

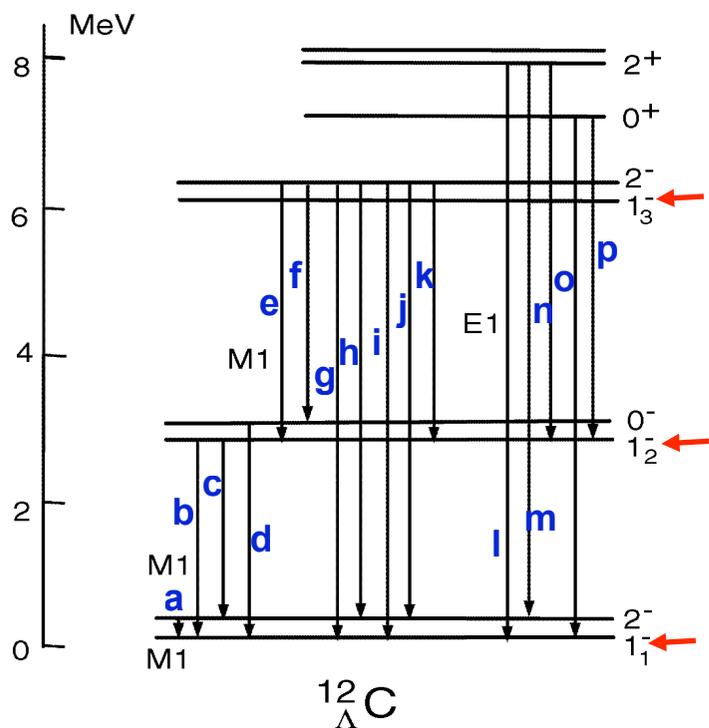
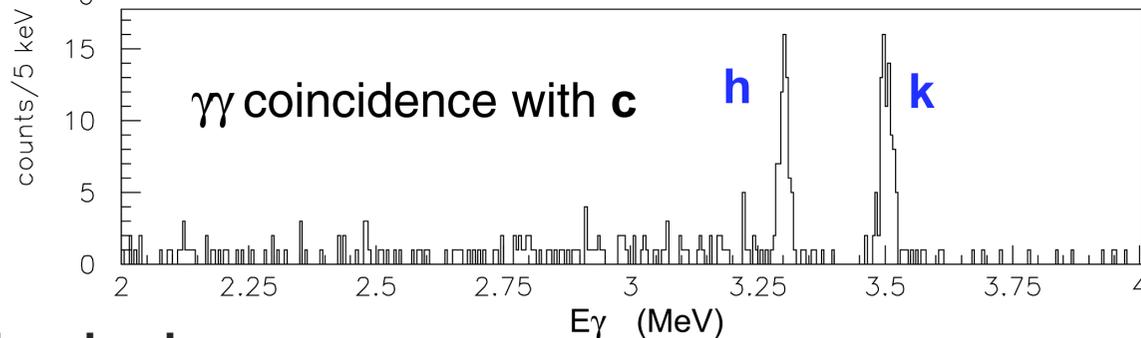
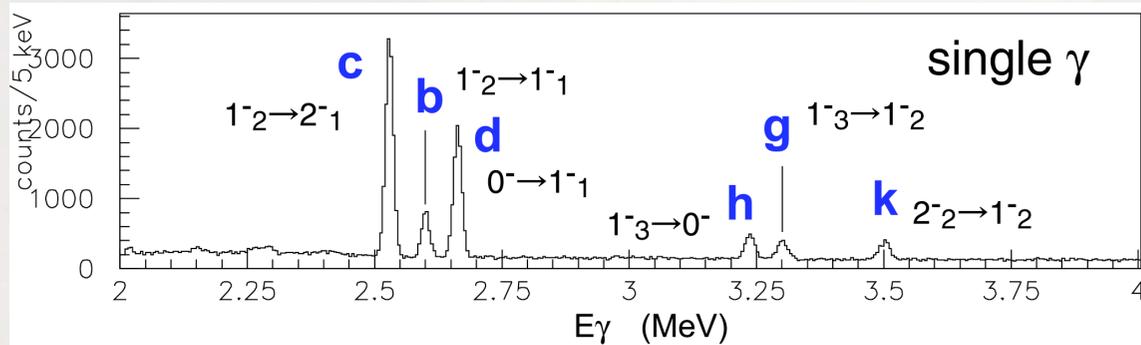
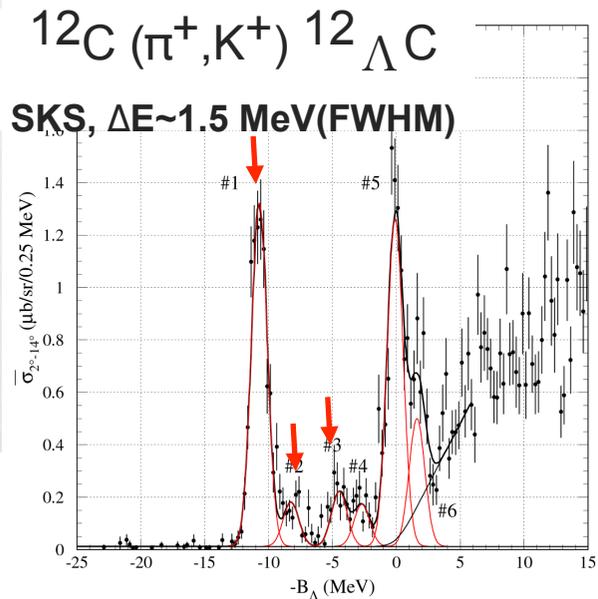
# Hyperball-J at J-PARC

- effic.  $> 10\%$  at 1 MeV  
(x4 of Hyperball)
- Rate limit  
 $\sim 2 \times 10^7$  particles /s (x5)
- Yield: x20 for single  $\gamma$   
x80 for  $\gamma\gamma$



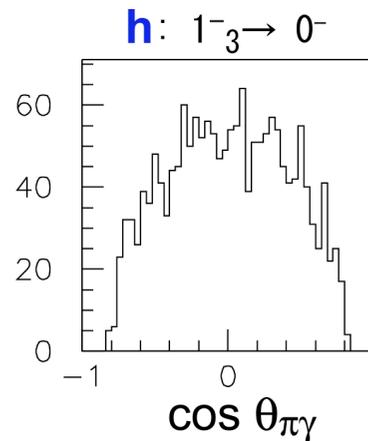
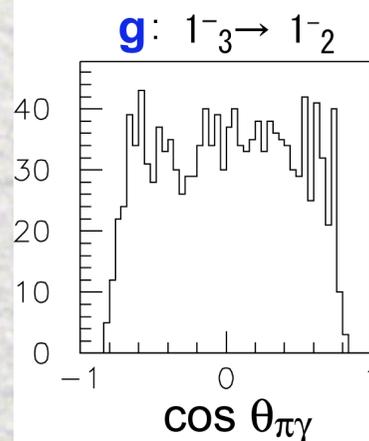
# $\gamma - \gamma$ $^{12}_{\Lambda}C$

Simulation: K1.1, 10g/cm<sup>2</sup>, 120 hours



-> level scheme

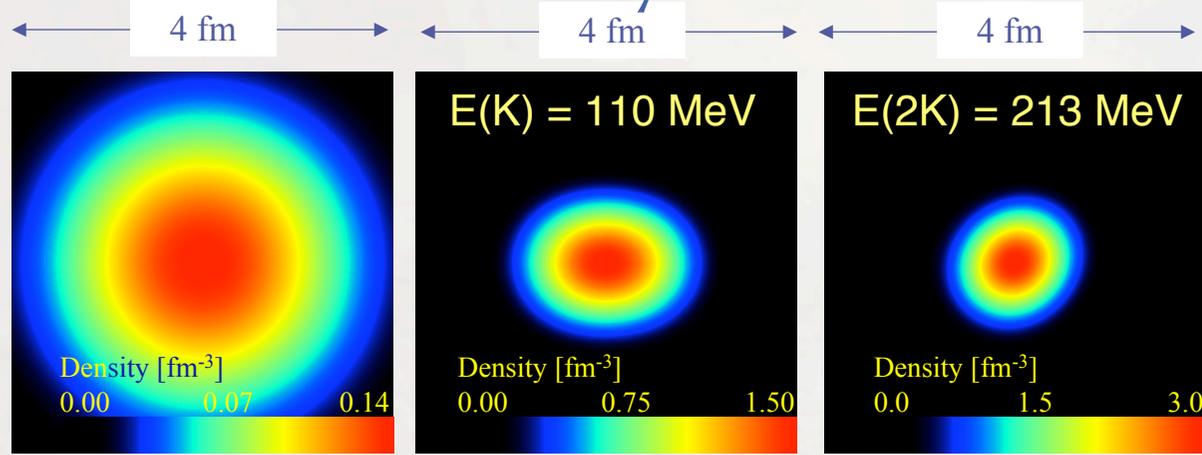
Angular corr.  
-> spin assign



# L10: Study of Dense Kbar-Nuclear Systems

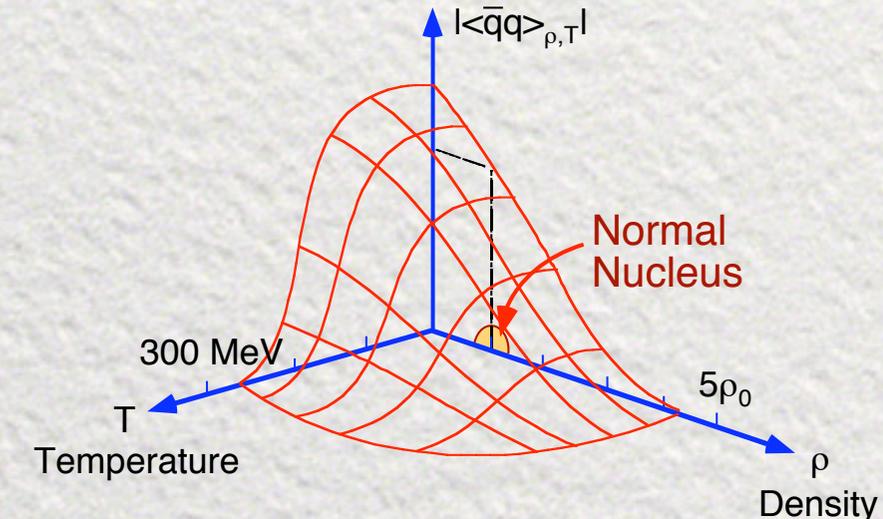
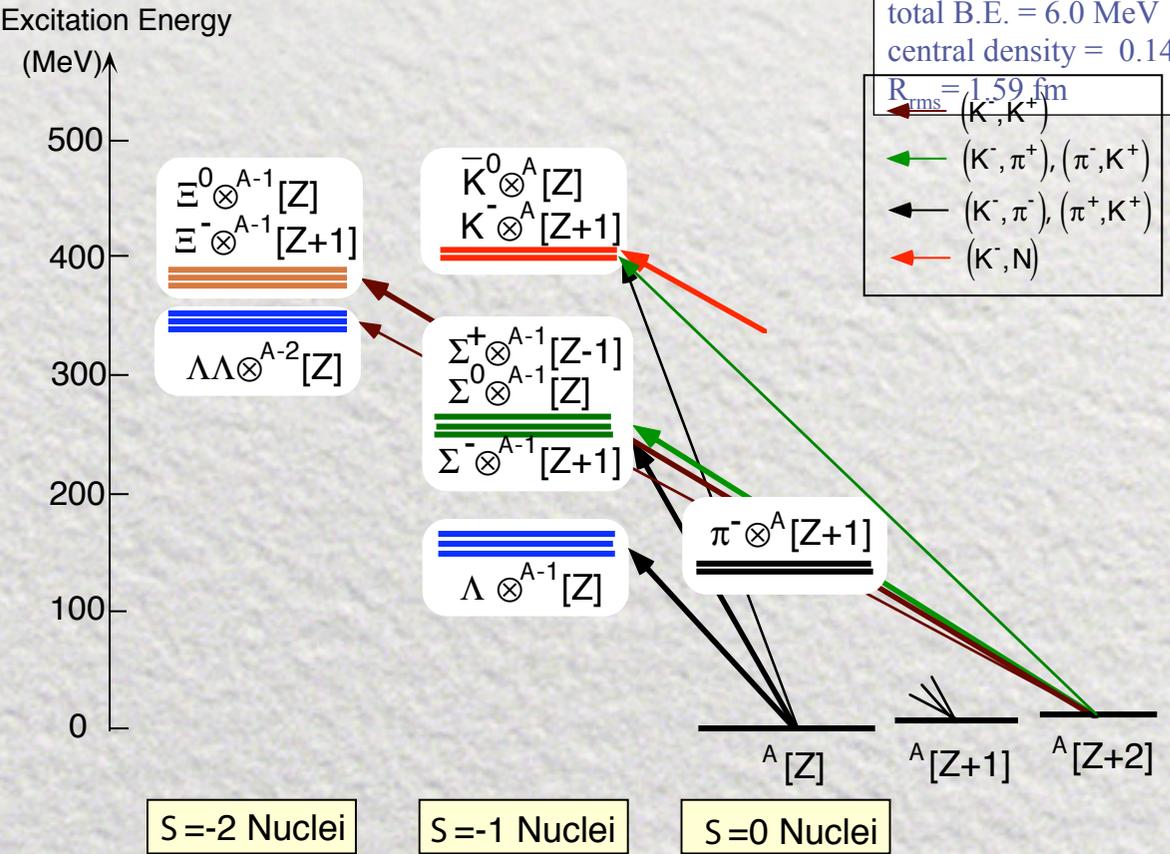
● New type of Strange Hadron Systems

● Cold and Dense

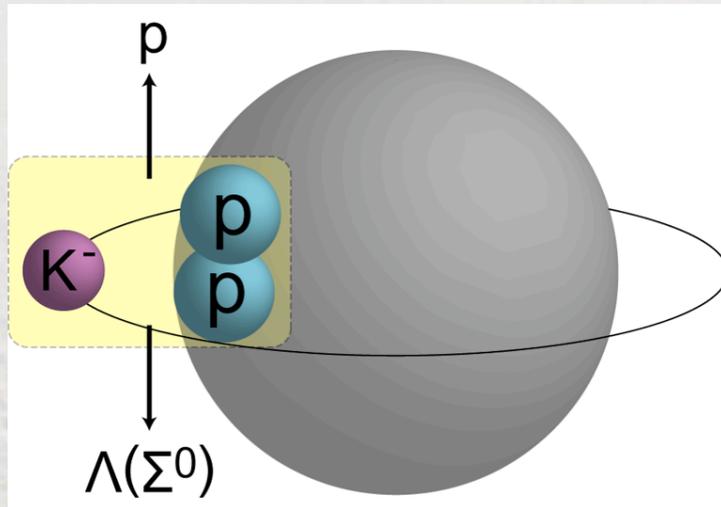


ppn	ppnK <sup>-</sup>	ppnK <sup>-</sup> K <sup>-</sup>
total B.E. = 6.0 MeV central density = 0.14 fm <sup>-3</sup> R <sub>rms</sub> = 1.59 fm	total B.E. = 118 MeV central density = 1.50 fm <sup>-3</sup> R <sub>rms</sub> = 0.72 fm	total B.E. = 221 MeV central density = 3.01 fm <sup>-3</sup> R <sub>rms</sub> = 0.69 fm

$\rho > \rho_0 \times 10 !!$



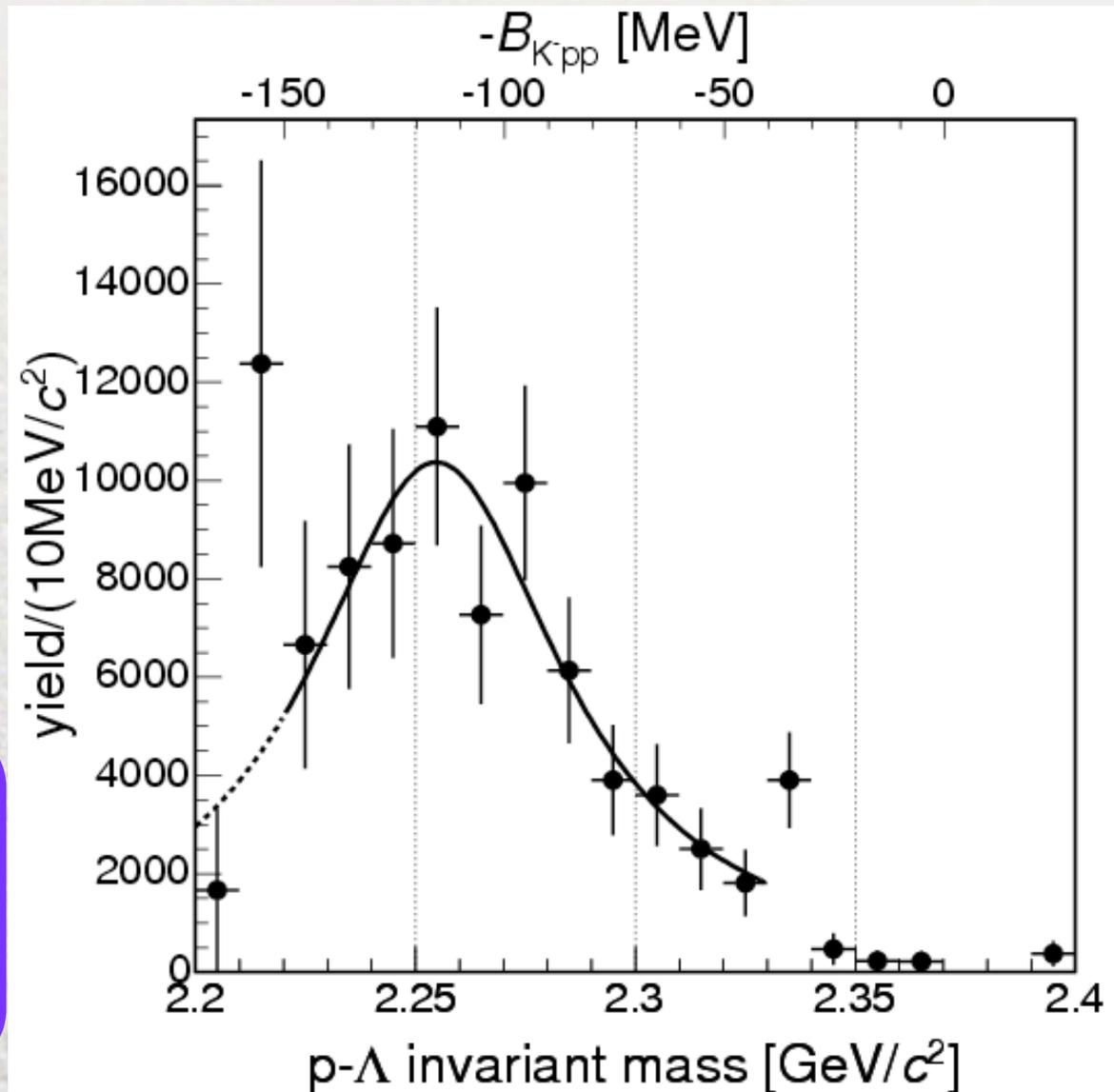
# FINUDA: Invariant mass method



PRL 94 (2005) 212303

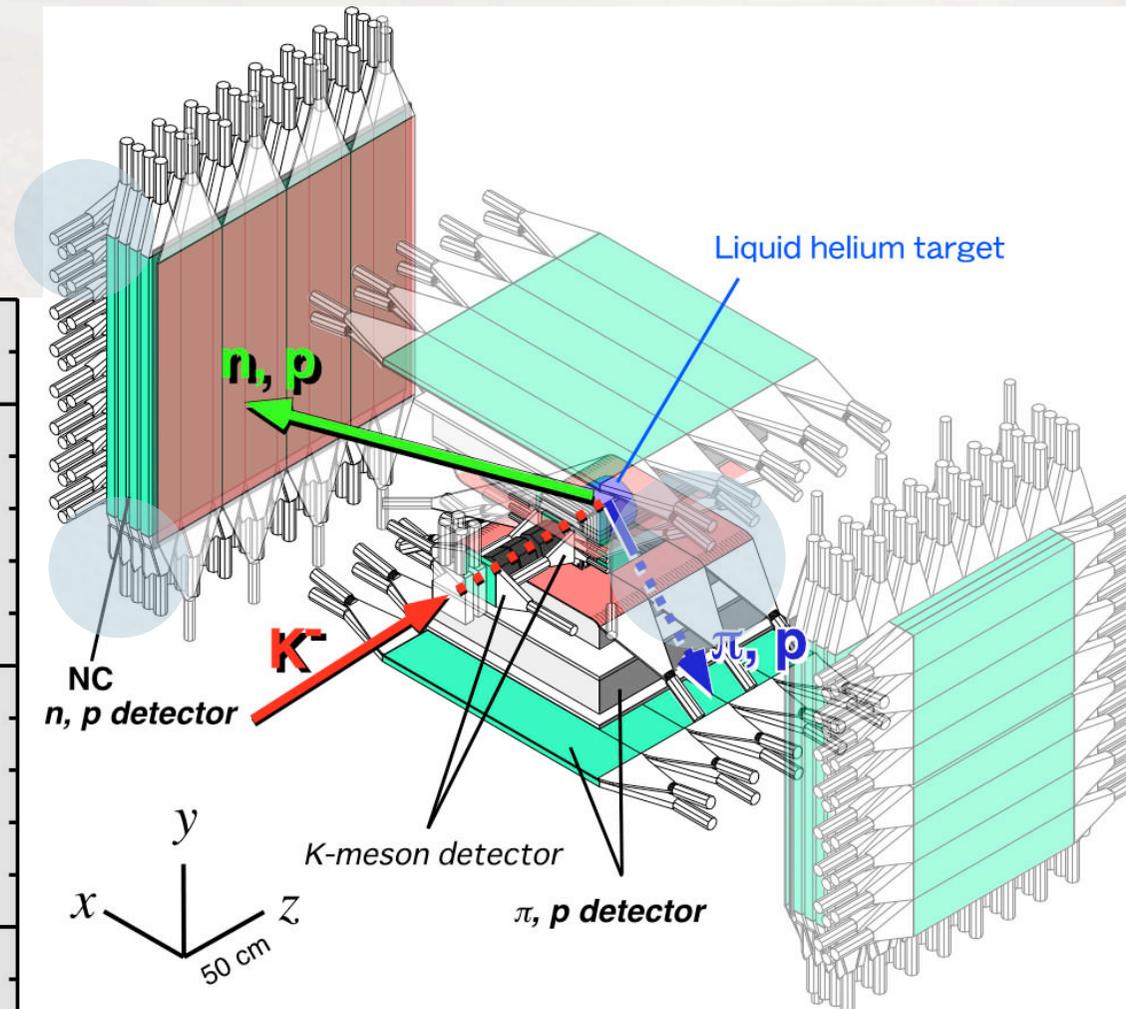
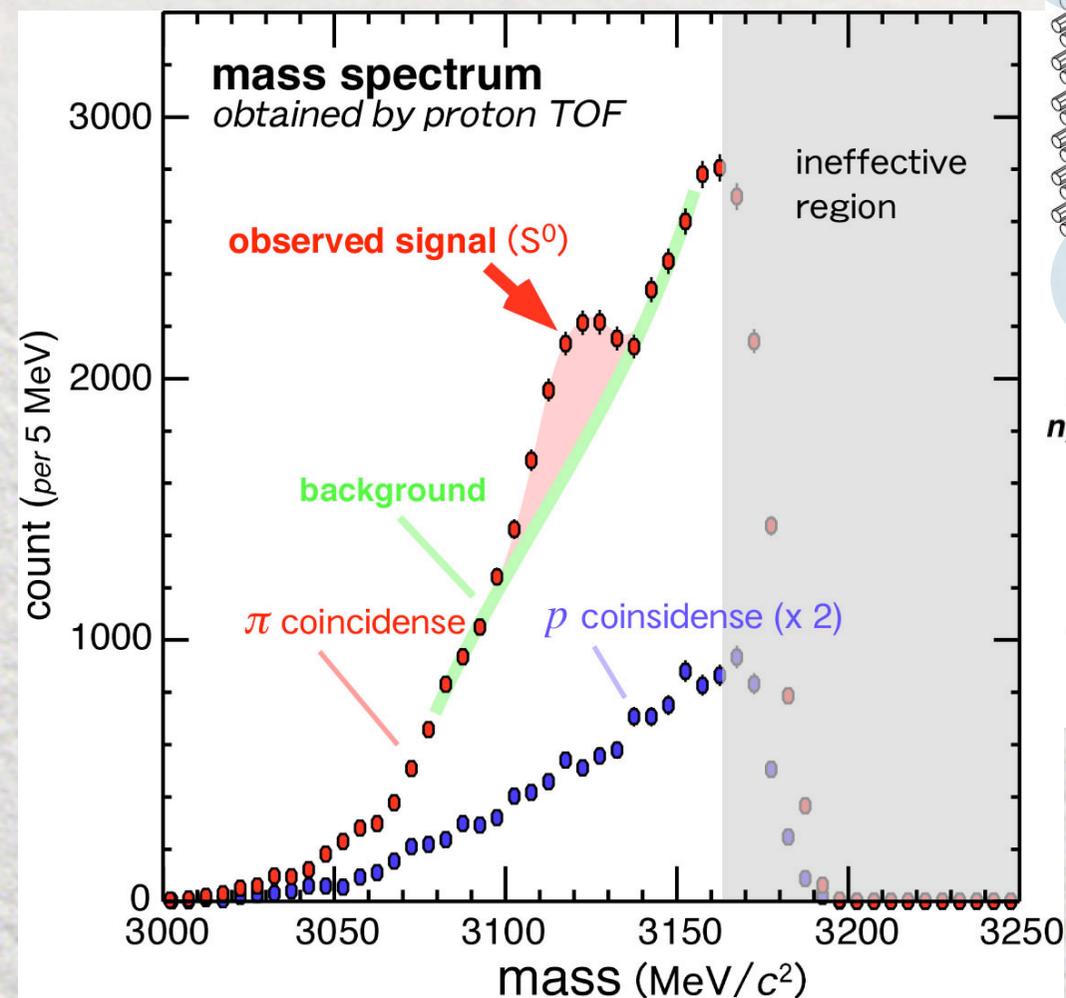
$$B = 115^{+6}_{-5} {}^{+3}_{-4} \text{ MeV}$$

$$\Gamma = 67^{+14}_{-11} {}^{+2}_{-3} \text{ MeV}$$



# Strange tribayon $S^0(3115)$

T. Suzuki *et al.* : PLB 597 (2004) 263-269

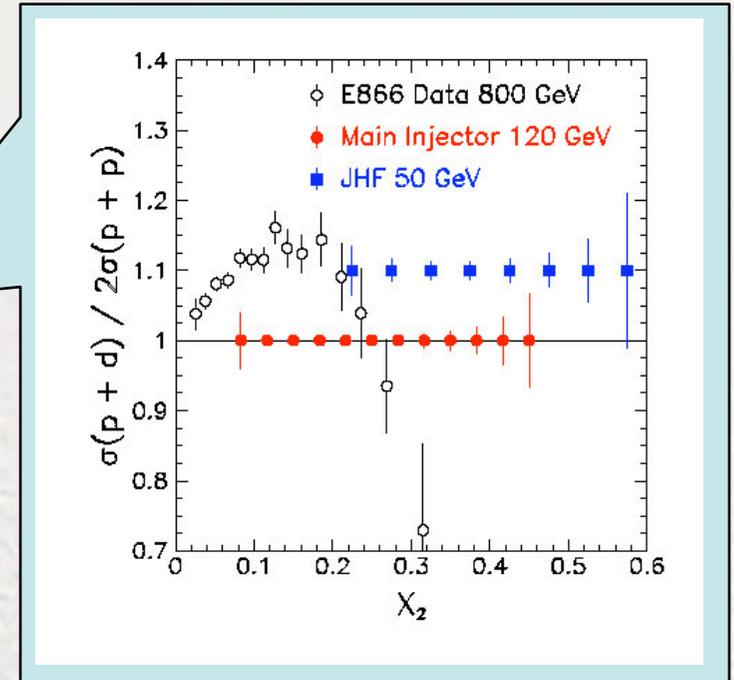
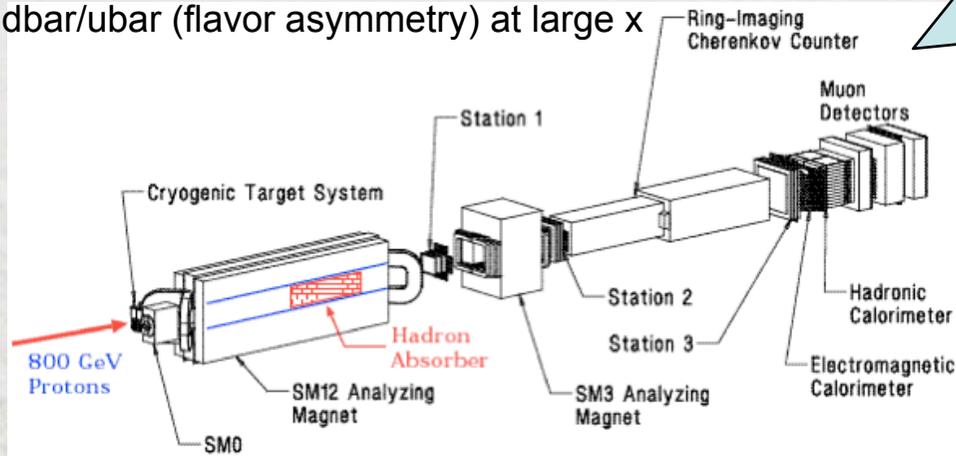


KEK E471  
 $^4\text{He}(K^-_{\text{stop}}, pX)$

# Hadron Physics Experiments

## L15: Sea Quark at Large $x_{Bj}$

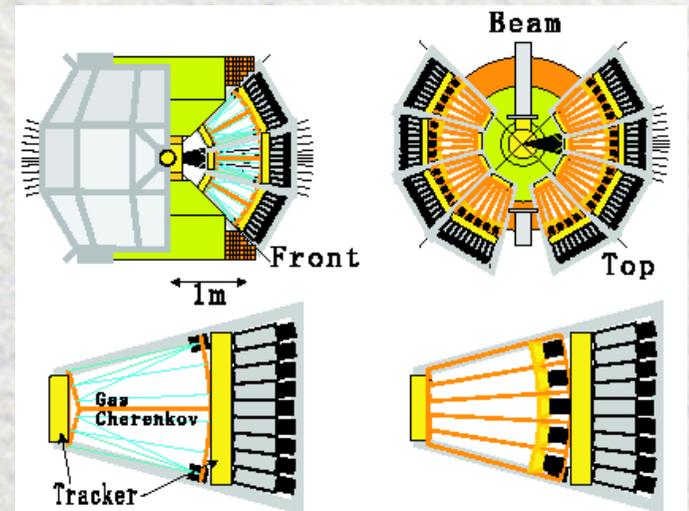
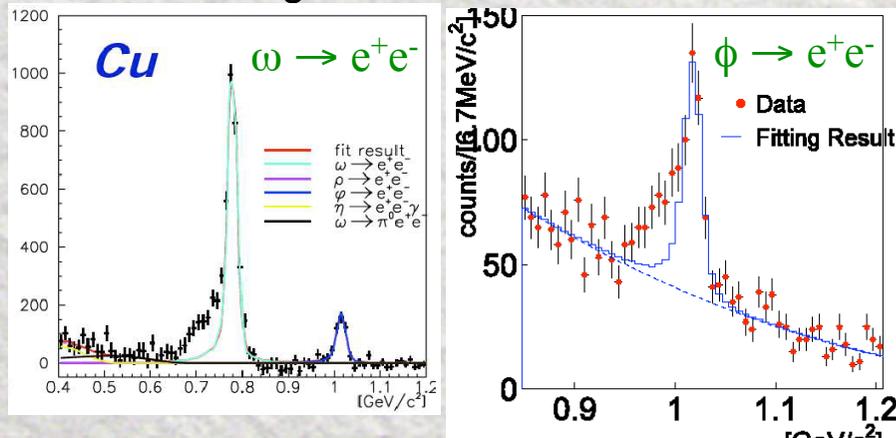
- Proton beams (50 GeV) + hydrogen/deuterium target + dimuon ( $\leftarrow$  Drell-Yan process) spectrometer
- $d\bar{b}/u\bar{b}$  (flavor asymmetry) at large  $x$



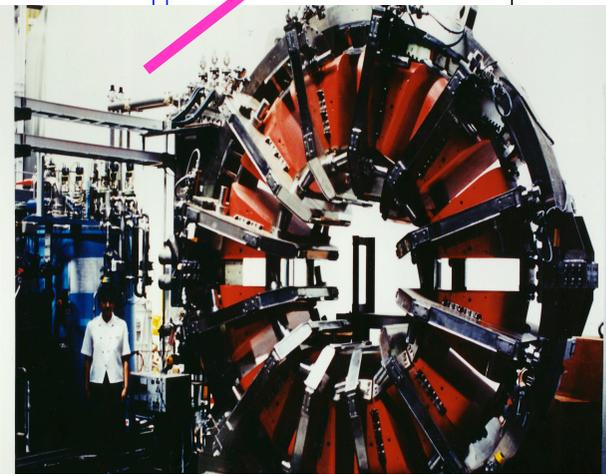
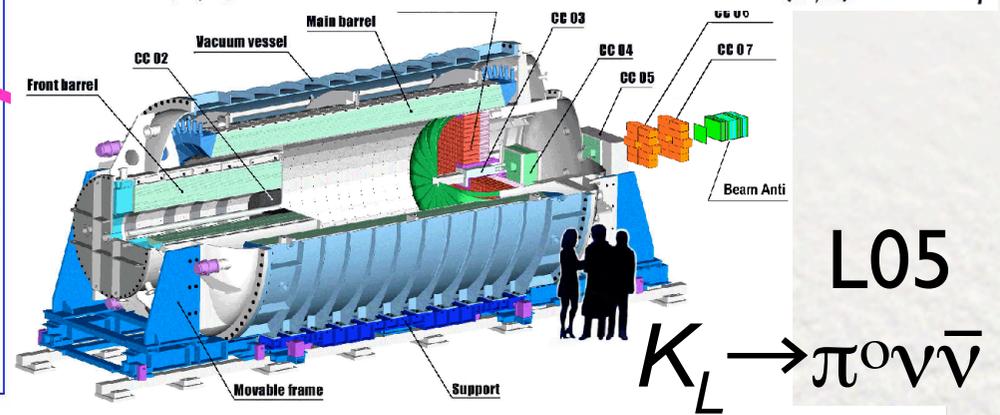
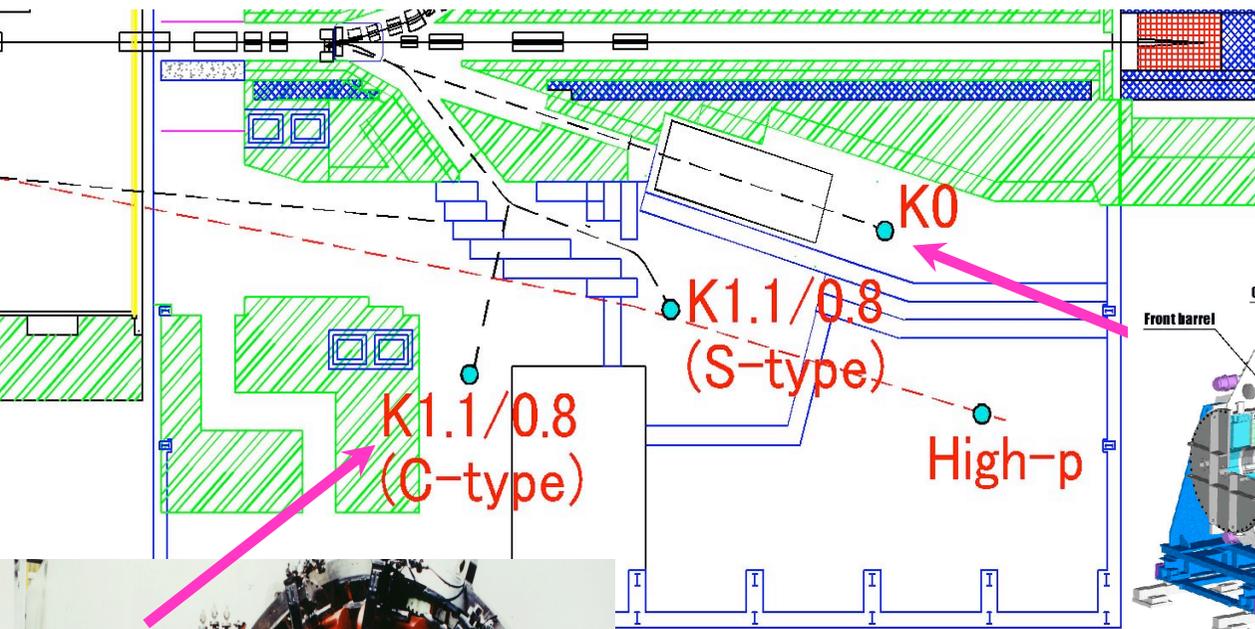
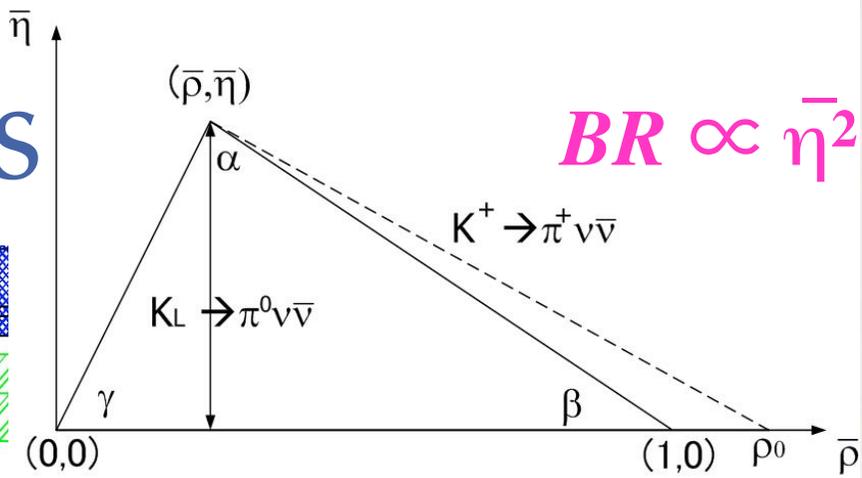
## L11: Vector Meson Modification in Nuclear Matter

Main goal : collect  $10^4 \sim 10^5 \phi \rightarrow ee$  for each target in 100 shifts

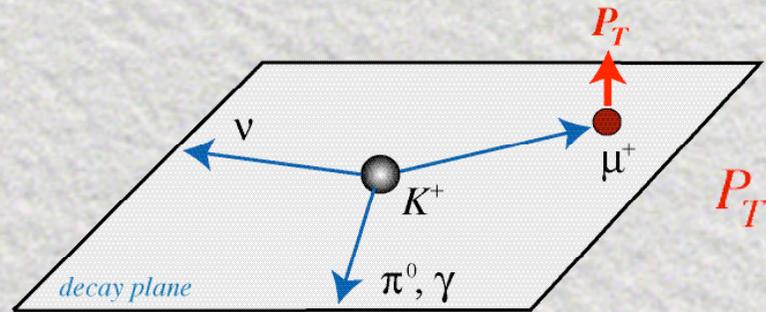
10-100 times as large as E325



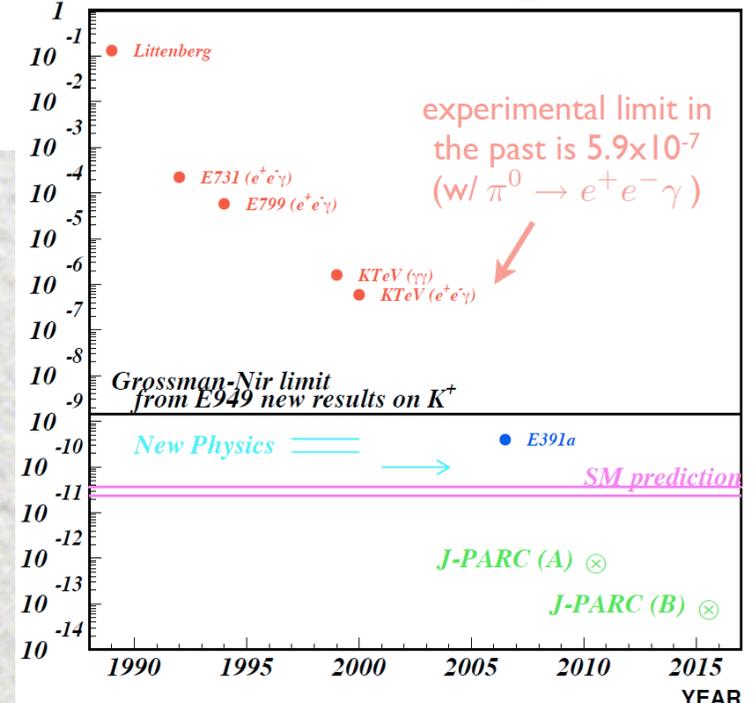
# K Decay Experiments



**L19**  
 T violation in  $K^+ \rightarrow \pi^0 \mu^+ \nu$   
 $\sigma(P_T) < 10^{-4}$



$$P_T = \frac{\sigma_\mu \cdot (p_{\pi^0, \gamma} \times p_{\mu^+})}{|p_{\pi^0, \gamma} \times p_{\mu^+}|}$$



# Neutrino Beam Facility

**$\sim 1\text{GeV } \nu_\mu$  beam  
( $\times 100$  of K2K)**

**Narrow Off-axis beam**

Super-K.



**Quasi-Monochromatic Beam  
Tuned at Oscillation maximum**

**Statistics at SK**

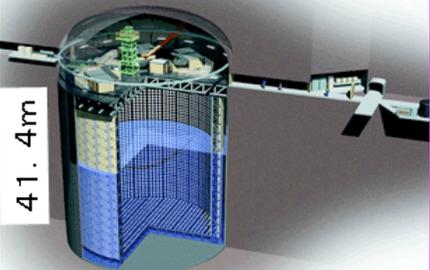
**(OAB 2.5 deg, 1 yr, 22.5 kt)**

**$\sim 2200 \nu_\mu$  tot**

**$\sim 1600 \nu_\mu$  CC**

**$\nu_e \sim 0.4\%$  at  $\nu_\mu$  peak**

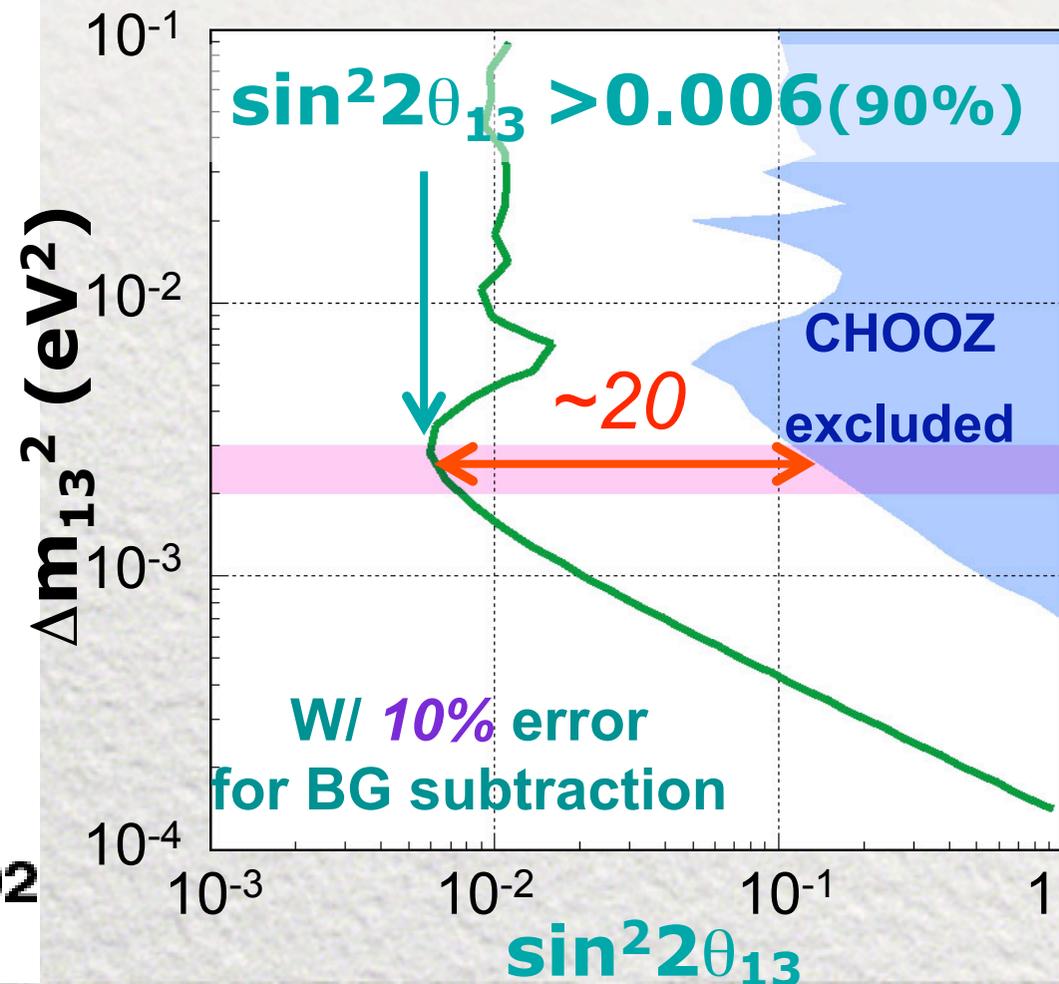
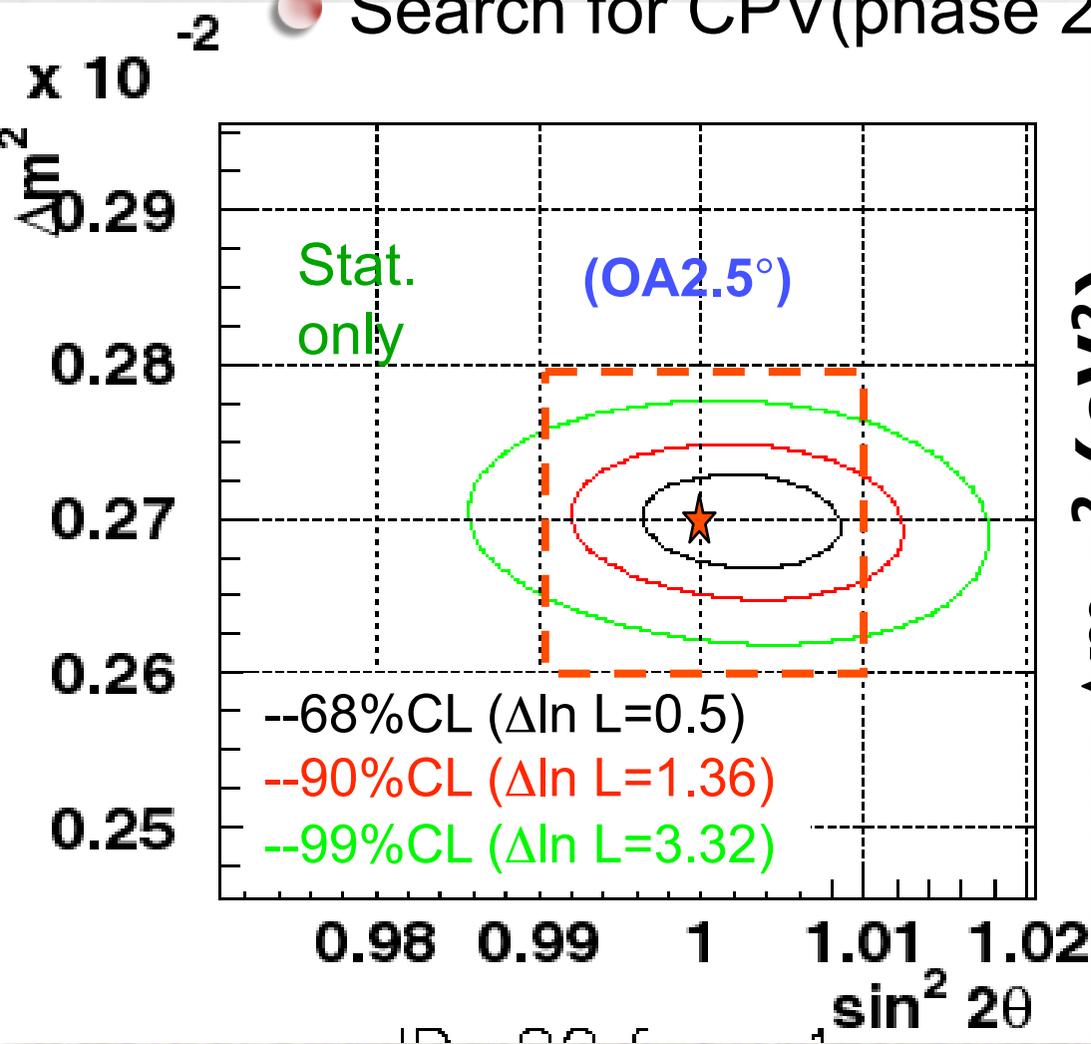
41.4m



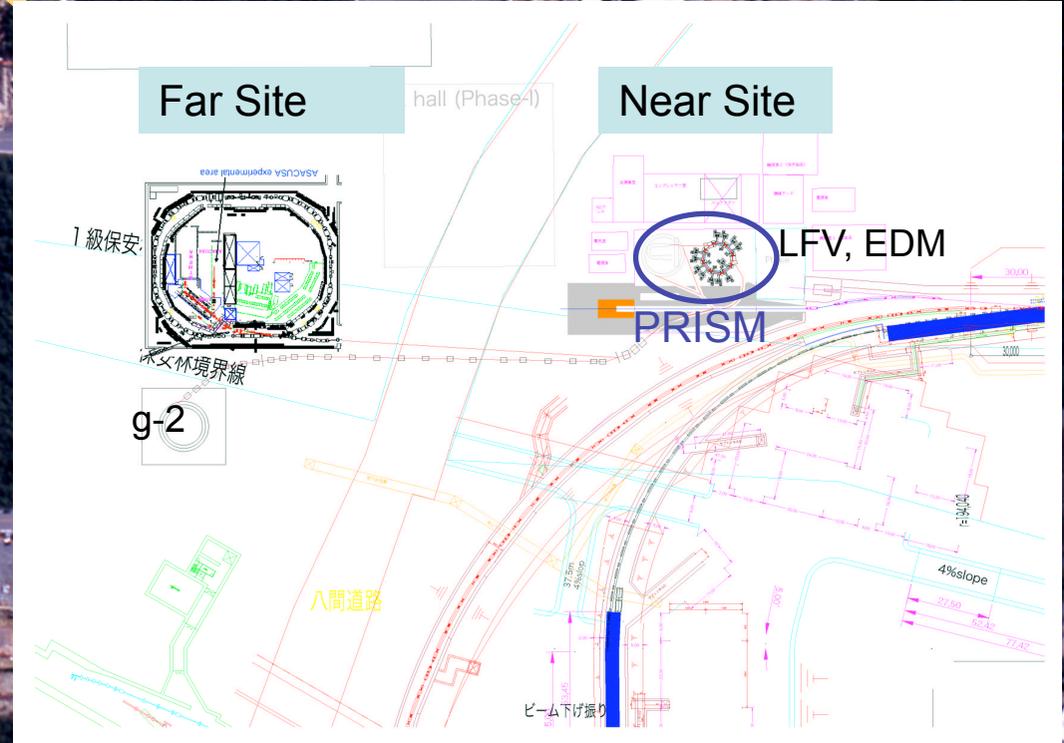
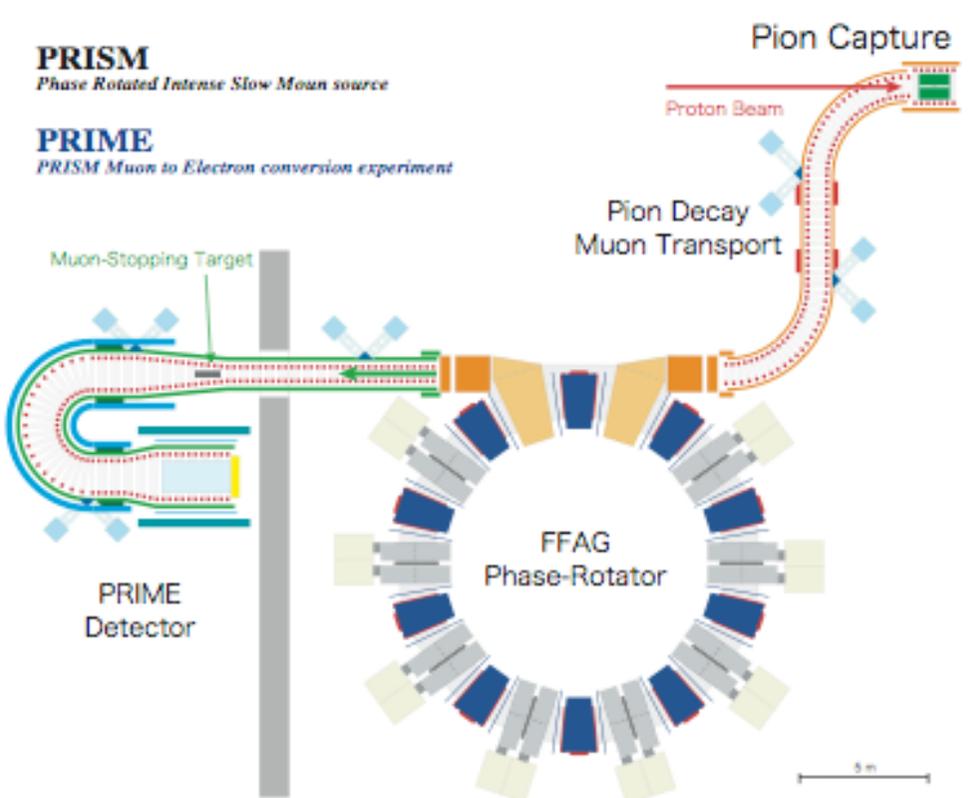
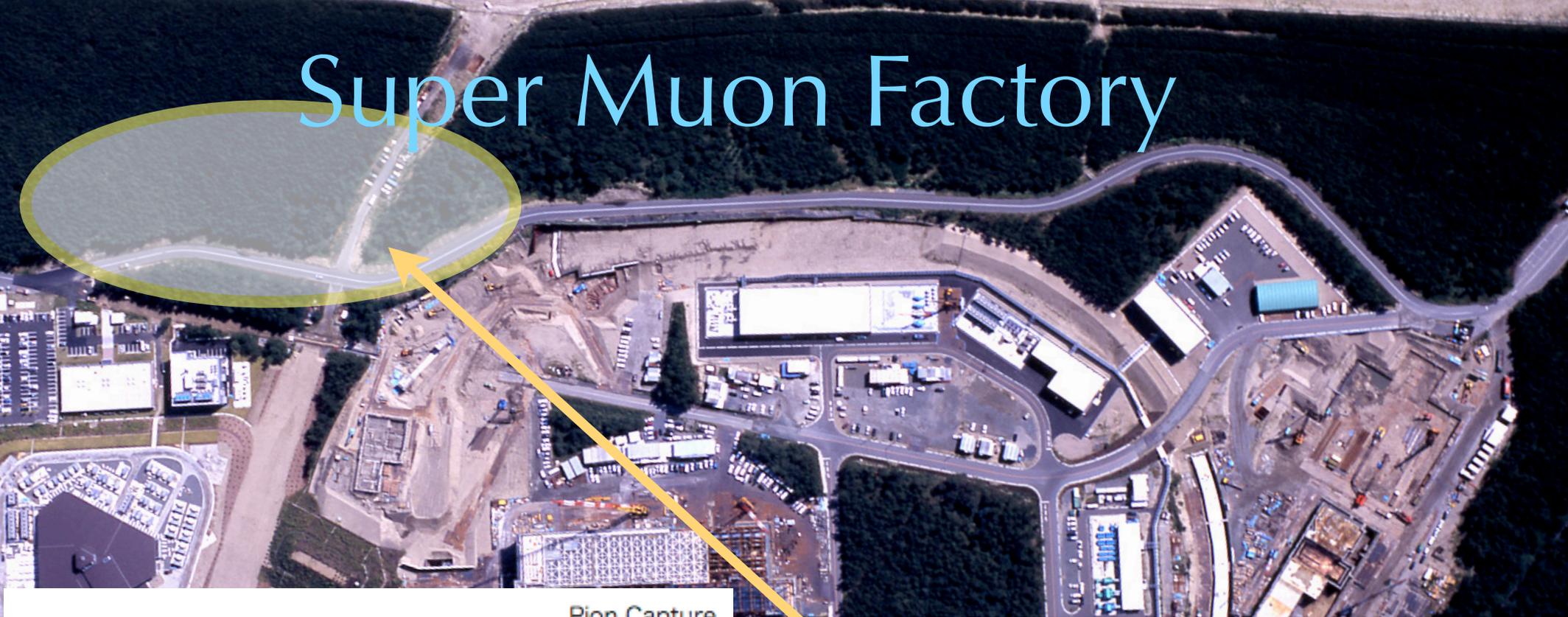
# L12: T2K Experiment

## Physics Goals

- $\nu_e$  appearance:  $\sin^2 2\theta_{13} > 0.006$  (90%CL)
- $\nu_\mu$  disappearance:  $\delta(\Delta m_{23}^2) \sim 10^{-4} \text{eV}^2$ ,  $\delta(\sin^2 2\theta_{23}) \sim 1\%$
- Search for CPV(phase 2):  $\delta > \sim 20 \text{deg}$



# Super Muon Factory



# Muon Physics at J-PARC

● L17: Muon g-2: Precision measurement

● 0.7 ppm → 0.05 ppm

● L22: Muon EDM: Suppressed process

●  $<10^{-19}$  e•cm →  $<10^{-24}$  e•cm

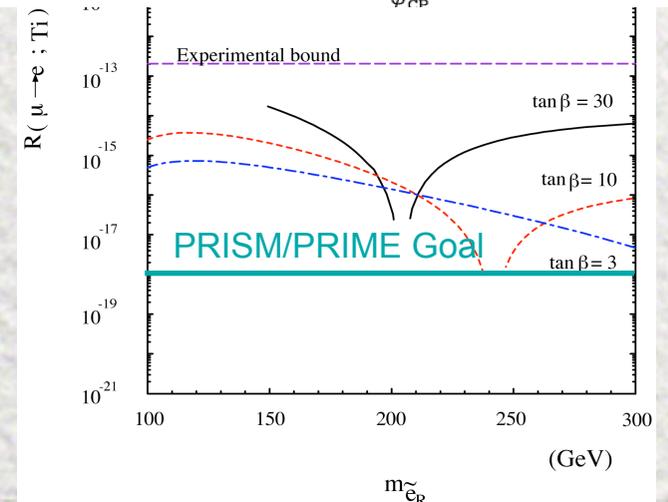
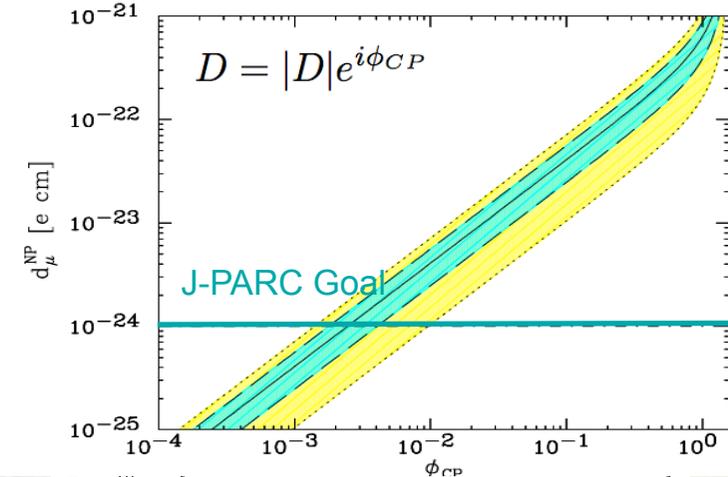
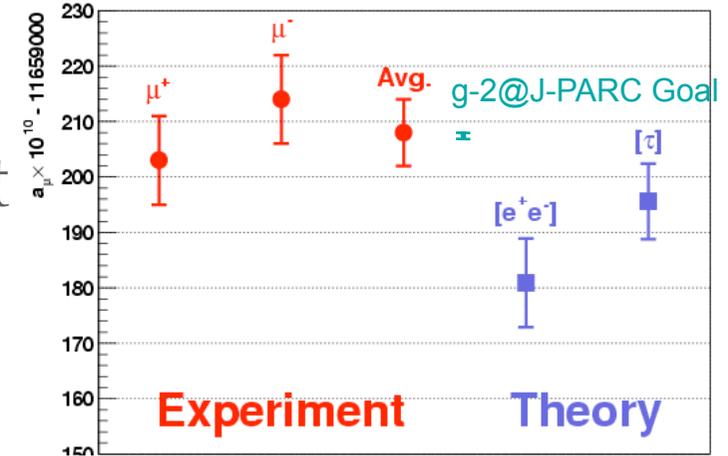
Unified Operator for g-2 and EDM

$$\mathcal{L}_{DM} = \frac{1}{2} \left[ D \bar{\mu} \sigma^{\alpha\beta} \frac{1 + \gamma_5}{2} + D^* \bar{\mu} \sigma^{\alpha\beta} \frac{1 - \gamma_5}{2} \right] F_{\alpha\beta}$$

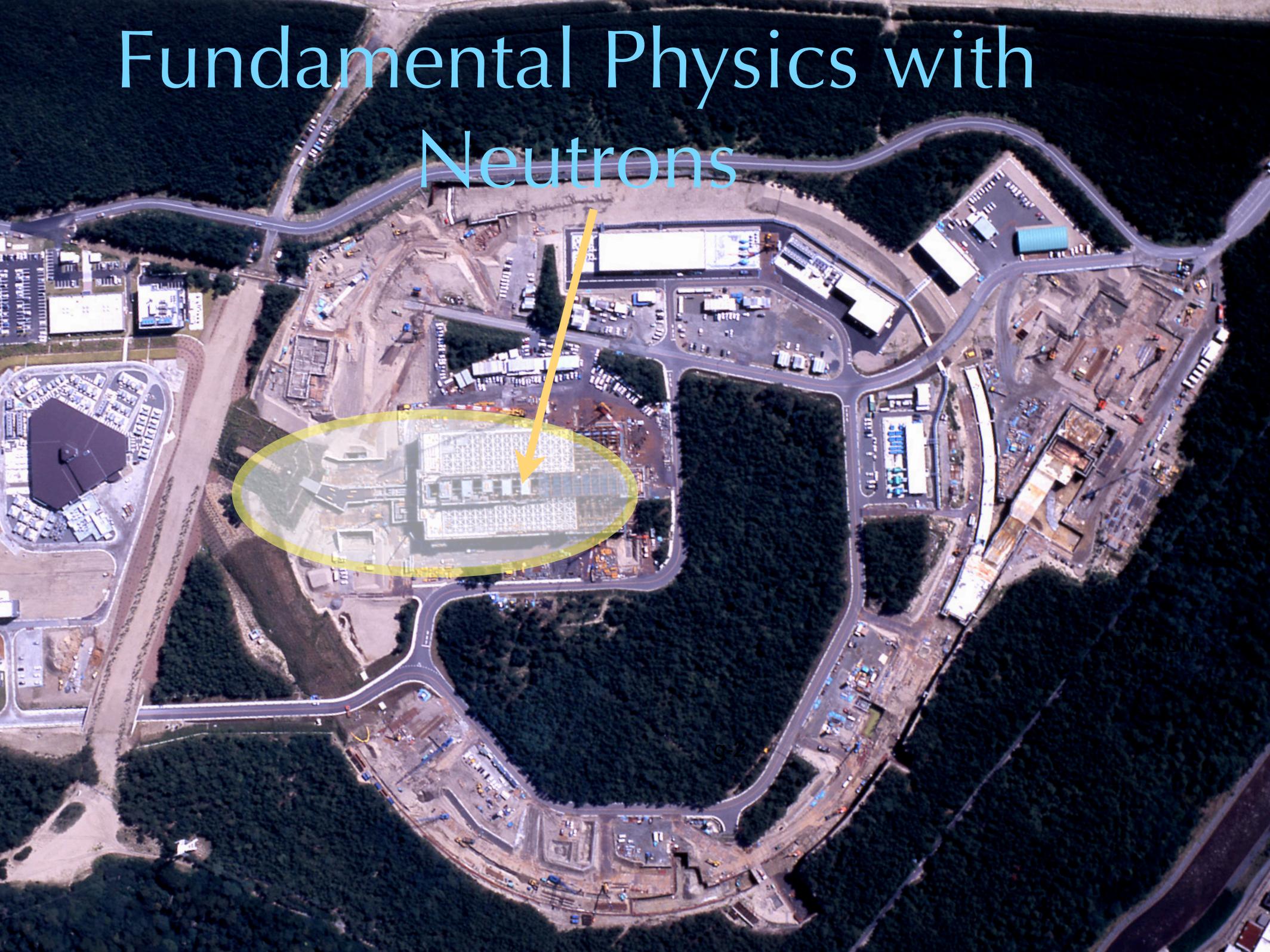
•  $\text{Re}[D]$  : g-2       $\text{Im}[D]$  : EDM

● L25: Muon LFV: Forbidden process

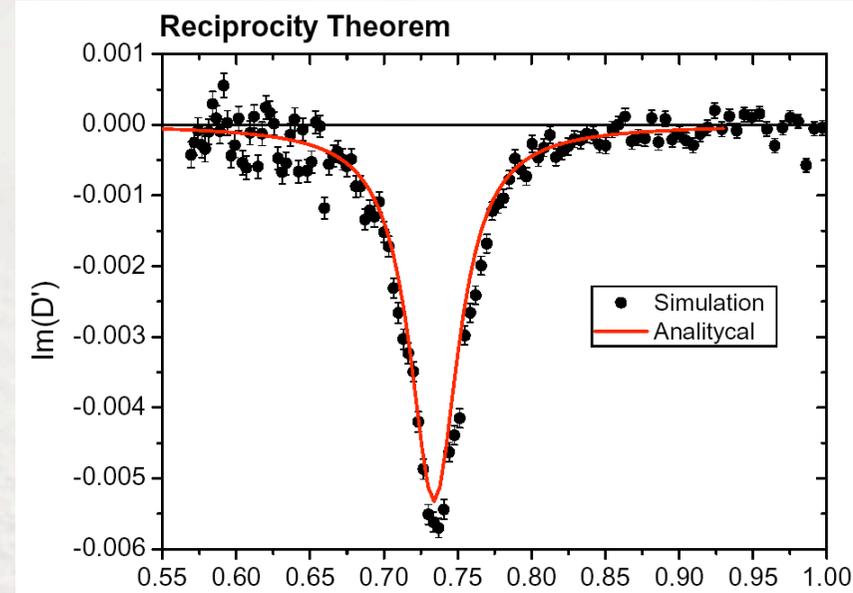
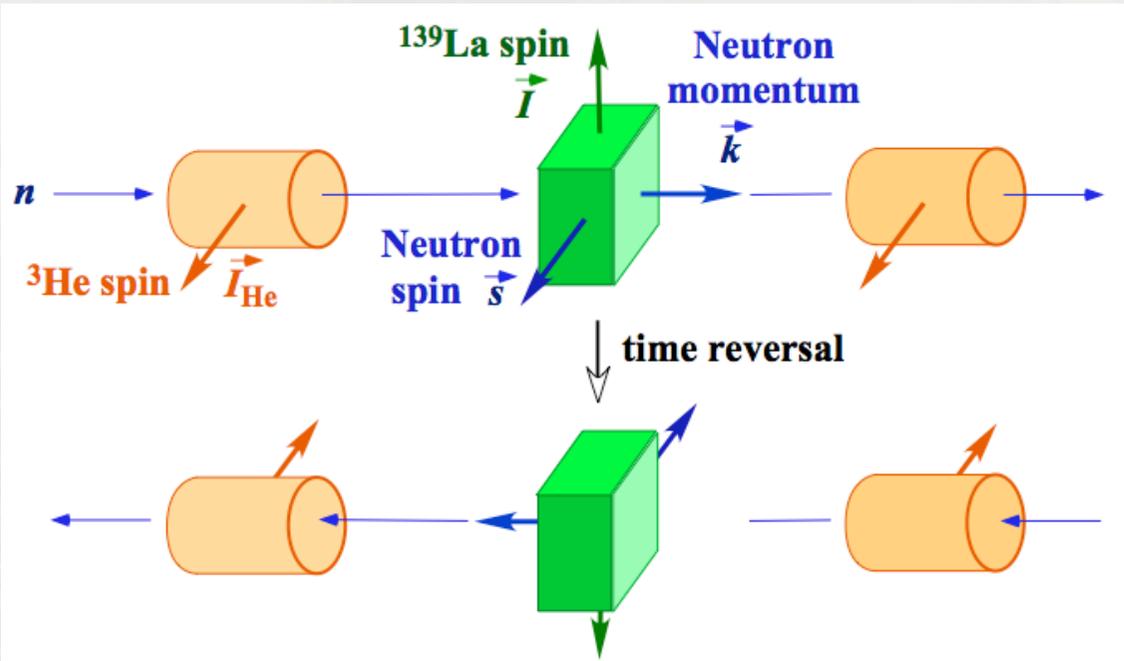
● SUSY-GUT ( $R=10^{-15}$ )



# Fundamental Physics with Neutrons



# Time Reversal of $n$ transmission



Monte Carlo for eV

$$\lambda = \text{Im}(D')/\text{Im}(C') = 1$$

$$\rho_t = 0.5, H_0 = 858 \text{ G}$$

Detector efficiency 100%

$$\rho_{\text{He}} = 0.6$$

Number of neutrons in  
0.5 to 1.0 eV =  $10^9$

counting time: 56 s

$3 \times 3 \times 3 \text{ cm}^3 \text{ LaAlO}_3$

at 20 m from J-PARC  
neutron source,

$$\phi = 4 \times 10^6 / \text{s} \cdot \text{cm}^2 \cdot \text{eV}$$

$$f = A + p_t B(\vec{s} \cdot \vec{I}) + C(\vec{s} \cdot \vec{k}) + D(\vec{s} \cdot [\vec{k} \times \vec{I}])$$

$$\lambda = \text{Im}(D)/\text{Im}(C) = 10^{-4}$$

$\rightarrow n$  EDM of  $10^{-26} \sim 10^{-27} \text{ cm}$  V.P.Gudkov

$1.5 \times 10^7 \text{ s}$  for a measurement of  
 $\lambda = 10^{-4}$  at J-PARC

# High density UCN source

	RCNP (Prototype)	J-PARC	PSI <sup>a</sup>	Los Alamos <sup>a</sup>
	He-II in 20K D <sub>2</sub> O	He-II in 20K D <sub>2</sub>	SD <sub>2</sub>	SD <sub>2</sub>
E <sub>p</sub> (MeV)	400	500	600	800
I <sub>p</sub> (μA)	4	60	2000	100
on/off (s)	150/450	150/450	8/800	0.4/10
(E <sub>p</sub> × I <sub>p</sub> ) <sub>av</sub> (kW)	0.4	7.5	12	3.2
τ (s)	150	150	888 <sup>b</sup>	2.6
E <sub>c</sub> (neV)	100	190	250	250
ρ (UCN/cm <sup>3</sup> )	<u>280</u>	<u>3 × 10<sup>5</sup></u>	<u>3 × 10<sup>3</sup></u>	<u>120</u>
( E <sub>c</sub> = 100neV	<u>280</u>	<u>1 × 10<sup>5</sup></u>	<u>750</u>	<u>30</u> )

<sup>a</sup> ICANS-XVI, April 2005

<sup>b</sup> storage time of more than 800 s is reported.

*n* EDM of 10<sup>-26</sup> ~ 10<sup>-27</sup> cm  
G<sub>A</sub> and G<sub>V</sub> with δ = 10<sup>-3</sup> from *n* β decay

*n*-nbar oscillation time of 3 × 10<sup>9</sup> sec.

# Summary

- J-PARC Center will be established in Feb., 2006
- Slow-extraction beams @30 GeV: in Fall, 2008
  - Day-1 experiments in Strangeness Nuclear Physics
  - K Decay experiments, Hadron Physics, ...
- Neutrino beam @40 GeV: in April, 2009
  - T2K Experiment
- Proposal Call will be announced very soon:
  - Deadline = End of March, 2006
  - PAC consideration in Spring, 2006

**Workshop on**

# **Hadron Structure at J-PARC**

**November 30 - December 2, 2005, KEK, Tsukuba, Japan**

**Physics Topics:**

**Hadron Physics with Neutrino Beam**

**Hadron Physics with 50 GeV Proton Beam**

**- Polarized Beam and/or Target**

**Exotic Hadrons**

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